

PHOTOGRAPH THIS SHEET

AD-A955 707

DTIC ACCESSION NUMBER

LEVEL

INVENTORY

Rept # 880-74
DOCUMENT IDENTIFICATION
MAY 1974

DISTRIBUTION STATEMENT

ACCESSION FOR

NTIS GRA&I ☒

DTIC TAB ☐

UNANNOUNCED ☐

JUSTIFICATION

BY

DISTRIBUTION /

AVAILABILITY CODES

DIST

AVAIL AND/OR SPECIAL

A-1
DISTRIBUTION STAMP
STATEMENT "A" per Dr. Bogard
Air University Library
Maxwell AFB, AL
TELECON 10/12/89 CG

DATE ACCESSIONED

DATE RETURNED

89 10 5 0 21

DATE RECEIVED IN DTIC

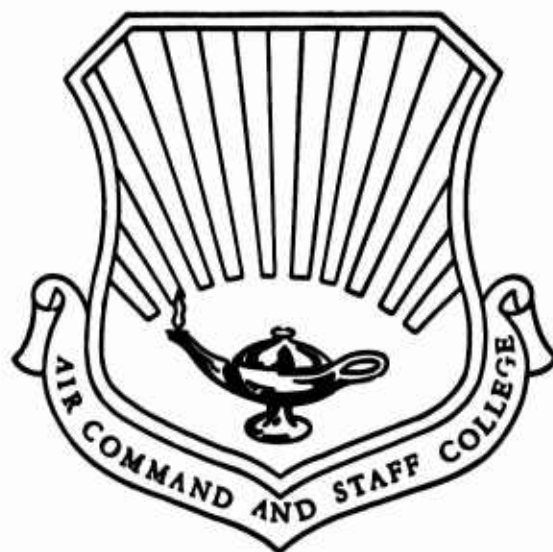
REGISTERED OR CERTIFIED NO.

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-PDAC

AD-A955 707

AIR COMMAND AND STAFF COLLEGE

RESEARCH STUDY



AIR UNIVERSITY

REPORT NO. 880-74

This study represents the views of the author and does not necessarily reflect the official opinion of the Air Command and Staff College, Air University, or the Department of the Air Force.

This document is the property of the United States Government and is not to be reproduced in whole or in part without permission of the Commandant, Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama.

AIR COMMAND AND STAFF COLLEGE

THE USE OF THE DELPHI METHOD
WITHIN THE DEFENSE DEPARTMENT

By

Gerald F. Elsbernd, [REDACTED]

PII Redacted

Major, USAF, 1934-

A RESEARCH STUDY SUBMITTED TO THE FACULTY

May 1974

AIR UNIVERSITY
MAXWELL AIR FORCE BASE, ALABAMA

Air University Library
Maxwell Air Force Base, Ala.
PROPERTY U. S. AIR FORCE

A RESEARCH PAPER

Submitted to

The Graduate Faculty of

Auburn University

In Partial Fulfillment of the

Requirements for the

Degree of

Master of Business Administration

AUBURN, ALABAMA

May 1974

ABSTRACT

The Delphi method is a new procedure devised to improve the usefulness of an intuitive judgment produced by a group of experts. Intuition is useful for judgments involving a high degree of opinion, such as value judgments and some forecasting applications. Analytical forecasting techniques are compared briefly with conventional intuitive methods, which are further compared with the Delphi method. The Delphi method is explored in considerable detail including a survey of experimental results and practical applications. Conclusions are provided concerning the applications of Delphi within DOD, with particular emphasis on technological forecasting applications.

TABLE OF CONTENTS

	Page
ABSTRACT	11
Chapter	
I. INTRODUCTION	1
Statement of the Problem	
Objectives	
Limitations	
Assumptions	
II. THE USEFULNESS OF INTUITION.	6
The Nature of Opinion	
Value Judgments	
Forecasting the Future	
Forecasting Methods	
Intuitive Methods	
Conventional Intuitive	
Forecasting Methods	
III. THE DELPHI METHOD.	20
An Example of Delphi	
Analysis of Example	
Experimental Results	
Precautions	
Advantages	
Disadvantages	
Variations of Delphi	
IV. APPLICATIONS OF DELPHI	46
Industrial Applications of Delphi	
Defense Department Applications	
Delphi Applications by other Agencies	
Delphi within the Soviet Union	

TABLE OF CONTENTS (CONT'D)

	Page
V. CONCLUSIONS AND RECOMMENDATIONS	56
FOOTNOTES	63
BIBLIOGRAPHY	70

CHAPTER I

INTRODUCTION

A new attitude toward the future has become apparent. . . . The future is no longer viewed as unique, unforeseeable, and inevitable; there are, instead, a multitude of possible futures, with associated probabilities that can be estimated and to some extent, manipulated. . . . The traditional methods of the social sciences are proving inadequate This situation is rapidly being remedied by the introduction of new methods Among the new methods that are under development is one that has become known as the "Delphi technique." It attempts to make effective use of informed intuitive judgment.¹

The Delphi method, invented by Olaf Helmer and Norman C. Dalkey about 20 years ago at RAND Corporation, is basically a new way to structure the interaction among a group.² With Delphi, members of a group are questioned anonymously (usually by questionnaire) several times. Between rounds of questioning, a summary of the group response is provided each individual to stimulate further thinking. Summaries of the group's comments on previous rounds may also be provided. The revised responses nearly always converge and the median of the final round

results is considered to be the judgment of the group.

The structure of Delphi seeks to eliminate the major objections to the use of either a single individual or a conventionally structured group for obtaining a judgment. The Delphi technique thus attempts to improve the reliability and usefulness of expert judgment. Although Delphi does offer some potential advantages when the use of expert intuitive judgment is appropriate, it is not a panacea and must be used with care.

Statement of the Problem

Since 1967 when the opening quotation was published, the Delphi procedure has been employed in many different types of applications. Yet, in spite of the generally widespread application of the method, the available literature shows little evidence of the use of Delphi within the Department of Defense (DOD). This apparent reluctance of DOD stands in striking contrast to past trends. Because of its concern for the future, DOD has often been a forerunner in applying new techniques. For example, DOD was a pioneer in applying techniques which are now commonplace in the field of operations research. This study investigates the nature of Delphi and the applications of the

Delphi method. This study will also address the question of whether or not Delphi should be applied to a greater extent. If the use of Delphi should be expanded, the most suitable circumstances for its use within DOD will be indicated.

Objectives

To provide a basis for understanding the potential applications of Delphi within DOD, the following objectives have been imposed upon this study:

1. Because Delphi is only one form of intuitive judgment, a basic understanding of intuitive judgment will be provided. This background is developed upon a framework based upon the nature of opinion and a functional division of intuitive judgment into value judgments and forecasts of the future. Value judgments are treated briefly, followed by a more detailed treatment of forecasting. Intuitive forecasting methods are compared with analytical forecasting methods. The objections to the use of conventional intuitive forecasting methods are also outlined.

2. A thorough understanding of the Delphi method will be presented. The procedures, precautions, major experimental results, advantages, and disadvantages of

Delphi are examined. Variations of Delphi are also considered.

3. Various past examples of Delphi will be surveyed. These applications include a cross section from the Soviet Union, industry, DOD and other governmental agencies. Emphasis will be placed upon the extent of usage and the diversity of applications.

4. Conclusions will be formed and recommendations will be made concerning the potential scope and the nature of Delphi's usage within the Defense Department.

Limitations

Several limitations have been placed upon this study. First, the material has been limited to sources which are available at the Air University Library. This limitation does not appear to be restrictive as the available source material seems to be varied and sufficient.

Next, in order to reduce administrative complications this study does not contain classified material. Unclassified sources adequately indicate the nature and extent of the use of Delphi for the purposes of this study.

Finally, comments concerning the potential future applications of Delphi are restricted primarily to technological forecasting and associated activities, such as any directly related planning. Although the possibilities

for the use of Delphi are extremely numerous and varied, technological forecasting is a major potential area for the use of Delphi. Inferences concerning the feasibility of any particular application will be possible because of the general nature of the majority of the material which will be presented.

Assumptions

During the survey of past DOD applications of Delphi, the assumption has been made that the use of Delphi would be clearly apparent or explicitly mentioned. This assumption is based on the newness of the method and the observation that sources usually, but not always, indicated the methodology which was being used. In all of those sources in which Delphi's use was discovered, the use of the method was prominently indicated.

CHAPTER II

THE USEFULNESS OF INTUITION

This chapter considers the nature and applications of intuition with the aim of identifying those circumstances for which the use of intuition is preferable to the use of analytical methods. This understanding will provide a basis for judging the merits and potential applications of one form of intuitive judgment, the Delphi method.

The Nature of Opinion

Every judgment is based upon a considerable amount of information and the correctness of this input information determines, to a great extent, the worth or utility of the judgment. Each fragment of information can be arranged on a scale which indicates the probability that the information is correct.¹ Information that has no basis in fact would be on one end of the scale and this information is called speculation or guessing. Information which is certain to be correct would be on the other end of the scale; this information is called knowledge. Decisions are rarely based upon perfect knowledge because these judg-

ments would be trivial. On the other hand, speculation often gets into long-term policy decisions inadvertently.²

The vast mass of information which lies between speculation and knowledge, based upon some evidence but not fact, is called opinion. Other common names for opinion are wisdom, insight, experience, and informed judgment.³ Because opinion is imperfect, fragmentary, and incomplete information, it is characterized by a broad range of diversity among individuals. Consequently, judgments based upon opinion will also vary considerably between different individuals.⁴

When based on a high degree of opinion, the variety of resulting judgments creates a problem of determining which judgment should be used. The highest authority in an organization may feel compelled to make a judgment to prevent disagreement. If the authority is not an expert, an alternative is to use one or more experts to provide credibility to a judgment. Besides the potential acceptance gained through the use of experts, there are other more compelling reasons for their use. The experts have gained their reputation because they possess a few more fragments of information, understand the essentials of the problem better, or utilize their partial information more efficiently in order to arrive at better judgments

more consistently.

The process by which an expert or anyone else uses a high degree of opinion to arrive at a judgment is called intuition. Intuition is not necessarily irrational or illogical; it merely means that the mental processes involved in the judgment are not fully defined. In common usage, intuition has taken a meaning from the phrase "woman's intuition" and has come to mean a judgment based on speculation. However, a more proper meaning of intuition is "a synoptic grasp of many interrelated aspects of a complex problem."⁵ A synergistic effect occurs which often makes the intuitive judgment better than one based on the explicit formulation of the underlying opinions. In other words, the human mind can subconsciously weigh the correctness, the importance, and the interrelationship of each piece of fragmentary information in a highly efficient manner.⁶

To summarize thus far, intuition is useful for judgments whenever the best information available consists mainly of opinions; that is, whenever there is considerable doubt concerning the correctness of the available information. The use of experts maximizes the use of intuition primarily because they possess more information.

Value Judgments

To delve deeper into the use of expert intuitive judgment, the subject will now be functionally divided into value judgments and forecasts of the future. This classification is neither mutually exclusive nor exhaustive, but nevertheless it does provide insight. Forecasts of the future, which are representative of the broader class of factual judgments, will be considered in the next section.

Value judgments are subjective evaluations of an object or of alternatives. To evaluate something means to appraise it according to the appropriate rules of merit.⁷ Four elements are required for an evaluation: the value object, the aspect of value, the criteria or rules of merit, and the resulting value judgment. Although criteria can be quantified, they are open to question and do not constitute knowledge. Instead, to the extent that the criteria vary between individuals, value judgments are based on a high degree of opinion. Hence, value judgments frequently are a type of intuitive thinking.

Value judgments are based on an especially high degree of opinion and are particularly suited to intuitive judgment in those cases where there are many partially conflicting criteria.⁸ Examples of this type are complex decisions

which determine priorities, goals, or objectives.⁹ If the criteria are not explicit, the choice between alternatives is highly intuitive also. The criteria cannot be explicit if the consequences are unknown or if there exists uncertainty as to which consequence is preferable.¹⁰ The latter case can occur even if the criteria is an ethical code, because the multiple moral considerations of an outcome may be impossible to directly assess in terms of the code.

Forecasting the Future

Value judgments represent a subjective process in which intuitive judgment is necessarily present to some degree. On the other hand, objective or factual judgments can be based on nearly perfect knowledge and therefore can sometimes avoid the use of intuitive thinking. Certain types of factual judgments, however, can benefit from intuitive judgment. Forecasts of the future are excellent examples of this type because a high degree of opinion exists at the time of the forecast, even though the validity of the forecast can be checked against perfect knowledge at some future date.

Forecasts of the future have been selected to represent all factual judgments for which intuitive judgments have a potential utility. This has been done because a well-

defined body of knowledge regarding forecasting exists which allows a comparison between intuitive and analytical methods to be made. However, intuitive methods can also be applied to obtain factual judgments about past or present events if it is not feasible or if it is impossible to obtain factual data.

Forecasting does not necessarily exclude value judgments. Two general types of forecasts are possible, exploratory and normative.¹¹ Exploratory forecasts seek to determine what can be done in the future and thus are completely factual judgments. Normative forecasts, however, seek to determine what ought to be done in conjunction with what can be done, and in this sense, combine a value judgment with a factual judgment. Obviously, all other things being equal, a normative forecast is more suited to intuitive judgment because an additional element of opinion is introduced if the future goals are not widely accepted and formulated. Normative forecasts can be further divided into self-fulfilling and self-defeating forecasts. Self-fulfilling forecasts are meant to goad a nation or an organization into action. Similarly, self-defeating forecasts are also meant to incite action, such as the forecast that the Russians would be the first to land on the moon.

Within the last decade or so, a growing awareness of the importance of forecasting the future has developed

within our society. This awareness has been largely generated by the rapid technological changes which have taken place and also by the accelerating rate of this change.¹² Social scientists are likewise becoming interested in forecasting technological change because changing technology is a major cause of social change.¹³ In addition to forecasting the future, there is also a growing realization that the future can be planned and influenced. Thus, the interest in normative forecasting has grown. The planner does not have the choice of not forecasting the future; the choice is whether the forecast will be made openly and subject to examination or whether it will be made subconsciously within the mind of a single individual.¹⁴

Evidence of the growing determination to plan the future is present at many levels.¹⁵ Labor unions are sensitive to long-range issues such as automation. Similarly, industry is becoming aware of the social consequences of its actions as demonstrated by its growing concern for issues such as ecology. Within the Department of Defense, long-range planning has become institutionalized by the introduction of the programming-budgeting system. As another example, President Nixon recently announced a long-range plan to make this country self-sufficient in energy supplies.

New institutions have been formed and new methods of forecasting have been developed to better cope with the future. The foremost practitioner of the Delphi technique is the five-year old nonprofit Institute for the Future.¹⁶ Herman Kahn, author of Thinking the Unthinkable, has refined the use of scenarios as a forecasting tool at Hudson Institute. At MIT, Jay Forrester has developed systems dynamics as a major tool for forecasting. Other institutions such as Battelle Memorial Institute, Stanford Research Institute, and A. D. Little have shifted emphasis from hardware research to forecasting and planning.¹⁷

Forecasting Methods

To properly understand the role of intuitive forecasting, a brief description of other forecasting methods must first be presented. Although different authors classify forecasting techniques in many ways and sometimes identify over 100 different techniques, these numerous techniques are composed of a small number of basic methods. One reference gives four basic forecasting methods: morphological analysis, trend extrapolation, heuristic forecasts, and intuitive forecasts.¹⁸ Another reference lists the three basic methods as extrapolation of history, analytical models, and the use of experts.¹⁹ This section

describes the analytical methods; intuitive forecasting is described in the next section.

Morphological analysis is a method of "identifying and counting all possible means to a given end."²⁰ Common examples are PERT network or a contingency tree. Morphological analysis is not exactly a means of predicting which possibility will occur, but rather a method of organizing all of the future possibilities.

Trend extrapolation is essentially a method of curve fitting based on past data.²¹ Considerable judgment is required in choosing the proper equation to fit the data. In addition, the basic assumption is made that past trends will continue. This assumption becomes less valid the farther into the future the trend is projected. Therefore, trend extrapolation must be used with common sense, which is just another word for intuitive judgment. In addition, past data is often unavailable or incomplete.

Heuristic forecasts include analogies, the interrelationship of events, modeling, and simulation.²² Like trend extrapolation, heuristic forecasts are based on quantitative methods, but a much better understanding of the underlying phenomena is required for the use of heuristic methods. Again, intuition must be used to determine the appropriate model and the range of validity of the model.

Intuitive Methods

As shown above, analytical methods of forecasting, despite their quantitative appearance, implicitly contain some degree of intuition in their underlying assumptions, structure, and ranges of validity. Intuitive methods, on the other hand, explicitly depend on intuition as the major aspect of the forecast. In addition to the use of single experts, discussion groups, polls, panels, brainstorming sessions, and Delphi groups, intuitive methods also include gaming and scenarios.²³ Gaming and scenarios, although highly useful, are applicable in a rather special set of circumstances and will not be considered in detail.

The intuitive process used in forecasting is no different than in any other application. This process has already been discussed and will not be considered further. Instead, some specific advantageous uses of intuitive forecasting will be discussed. To some extent, these guidelines for the use of intuitive forecasting have validity for any other use of intuitive judgment and are not restricted to intuitive forecasting.

One of the co-inventors of Delphi has pointed out some advantageous applications of expert intuitive forecasting.²⁴ For example, experts should be used whenever there is insufficient data to use a quantitative method.

If there is no means of obtaining this data, experts must be used. Reliable data is impossible to obtain for rapidly changing circumstances or for long-range forecasts. Experts can be used to estimate the data to be used as input information for an analytical method or they can make the forecast directly. Even when an analytical method has applicability, expert intuitive judgment should be used to evaluate the entire process. Also, whenever future alternatives which involve moral issues such as social welfare are being considered, expert intuition has a role in the inherent value judgments. Finally, intuitive judgment should be used for tactical or strategic decisions in non-zero sum game situations.

Another major application of intuitive judgment is involved in the non-exact sciences where expert judgment must substitute for the laws which are found in the physical sciences.²⁵

However, the utility of intuitive forecasting depends upon the situation. The best method to use depends on many factors such as the context of the forecast, the relevance and accuracy of historical data, the degree of accuracy desired, the time range of the forecast, costs versus potential benefits, and the time available to produce the forecast.²⁶

Conventional Intuitive Forecasting Methods

Having now discussed the potential uses of intuition, the objections to conventional intuitive methods will next be examined. Conventional intuitive methods include individual experts, polls, panels, and other groups of experts.

There is considerable appeal to the idea of using the simplest form of intuitive forecasting--the single expert or genius forecaster. Using a certified forecasting genius is quick, efficient, and inexpensive. However, if either the certification or the genius is in doubt, the effects of a single individual's biases, idiosyncracies, and selective ignorance will attach great risk to the forecast.²⁷

The next simplest method is to poll a group of experts to average out the risk. Two difficulties are apparent. First, because no interaction occurs, the expert does not gain any extra information, may feel no commitment to the result, and may exert little effort. In addition, it may be impossible to reach a consensus on certain types of questions.

The common tendency is to use a committee or a discussion group of experts. In theory, the old saying that two heads are better than one is based on the belief that

the experts can interact in a manner which increases the amount of information available to each individual. It is equally true, however, that two heads also have more misinformation than one. In practice, groups do not interact in a manner which maximizes the information available to each individual.

There are three major faults of discussion group interactions: the influence of the dominant individual, noise, and group pressure for conformity.²⁸ Groups give undue influence to the individual who talks the most or the loudest. This influence is not necessarily related to the dominant individual's ability or expertise. Within the military, this characteristic is especially prominent because of status and rank differences in an authoritarian society. Additionally, much of a group's interchange is noise--communications involved in maintaining group harmony rather than solving the problem. This irrelevant or redundant information obscures the relevant information. Finally, the group pressure for conformity causes individuals to adopt the group position because of an unwillingness to create hard feelings. For this reason, a timid member has little or no influence despite any expertise he may possess. The bandwagon effect can also work in reverse. An individual may be reluctant to change his position after it has been publicly stated.

The preceding arguments do not imply that discussion groups do not have any important uses. Groups are highly useful for transmitting information, coordinating action, diffusing of responsibility, formulating policy, and other similar functions.²⁹ The above objections to the use of a group were concerned only with the ability of a group to arrive at an intuitive judgment based on opinion.

Another technique that has been used is brainstorming. This technique is structured to remove the influence of the dominant individual and thus to enhance the creativity of the group. It serves this useful purpose, but if an attempt is made to arrive at a consensus judgment, this creativity is lost.

In the next chapter, the structure of the Delphi method will be examined to determine how this new method attempts to overcome the objections to the use of discussion groups in arriving at intuitive judgments.

CHAPTER III

THE DELPHI METHOD

The name Delphi was originally proposed by philosopher Abraham Kaplan. Since then this name has been considered to be an unfortunate choice because the reference to the ancient Greek oracle, while attracting interest, has also endowed the method with an aura of mysticism and the occult.¹ This suggestion has been equated with a high degree of unreliability in the minds of many.

The Delphi procedures have three distinct characteristics: anonymity, controlled feedback, and statistical group response.² Within these broad guidelines, a large amount of latitude exists, making Delphi flexible and adaptable for use in conjunction with other methods and procedures. To begin to understand the features of Delphi and their relationship to improved group interaction, a brief example of Delphi will be given.

An Example of Delphi

The example which is presented here is quite simple because the response consists primarily of a single number. Value judgments or selections of alternatives

are not considered. Also, only a single question is considered; most Delphi studies consider numerous questions simultaneously. In the more extensive studies which are summarized later, references to more complex examples can be found.

This example is one of the questions used in a demonstration of the Delphi process conducted by Dr. Olaf Helmer at the First Annual Technology and Management Conference in 1967.³ The example was a demonstration of the method only and the validity of the response should not be judged critically. Other than this, personal reactions may be tested while the Delphi study is presented in sequential form.

The first questionnaire was initially given to 100 conference participants. Normally, participants would be solicited beforehand, advised of the purpose of the study, and informed concerning the procedures and their anonymity. In this case the participants were apparently either briefed orally or were already familiar with Delphi and this step was unnecessary.

On the initial questionnaire, participants were asked to estimate their forecasting ability relative to the group on a scale from 1 to 7. Of the initial 100 volunteers, 23 who rated themselves most expert on

all of the questions were selected to continue with later rounds. Self-evaluation of expertness is an option of Delphi which will be treated in more detail later.

The question was asked, "In what year will power generated by thermonuclear fusion become commercially competitive with hydroelectric power?" The results of the first round were analyzed to obtain the median and the inter-quartile range (IQR). The median, of course, is the middle answer or the 50th percentile of the answers. The IQR is the range of answers between the 25th and 75th percentile. Answers to the first questionnaire gave a median of 1990 and an IQR of 1979-2005.

A second questionnaire was distributed which contained the feedback of the median and the IQR of the first round. The participant's first round response was also included to emphasize that, with long delays between rounds, previous answers are sometimes forgotten. The second questionnaire asked everyone to reconsider his previous estimate and instructed him to change it if he wished. If the new answer was outside the IQR, the participant was requested to briefly state his reason for disagreement.

Analysis of the second questionnaire provided a median of 1985 and an IQR of 1977-2025. Arguments for an earlier

date were:⁴

Water shortage within 10 years will force this development.

Power demands, especially in connection with desalinization, will rapidly become so great that thermonuclear power production will be generally accepted.

Decentralization of population centers and cost of distribution favor nuclear power.

The next drought will be world-wide.

Arguments advanced for a later date were:

Fission-generated power is not yet commercially competitive; fusion-generated power still requires development of basic technology, with immense problems to overcome.

There is little economic incentive since electric power is cheap.

Tidal power is yet untapped.

The cost of hydro-electric facilities is shared, there is no fuel cost, and maintenance is lower.

Efficient containment of thermonuclear energy seems to be completely out of the question.

The summarized arguments above, the second round median, and the IQR were fed back on the third questionnaire which was otherwise unchanged. The results of the third round gave a median of 1985 and an IQR of 1980-2030. The arguments which were advanced became briefer and more pertinent. In favor of an earlier date, the arguments were:⁵

Pressures regarding this on government and industry will escalate exponentially.

The "out of the question" statement is of the form "airplanes will never fly".

Counter arguments for a later date were:

Technical feasibility of plasma containment is not demonstrated or in sight.

The earlier-date argument merely supports the case for fission-generated power,-- which may be the real competitor, rather than hydroelectric power.

The drought argument is too speculative for comment.

These arguments and the third round results were fed back again in the fourth and final questionnaire. Only the answer without further arguments was requested because this was the final round. The final median was 1990 with an IQR of 1985-2030.

As a comparison, a group of 23 RAND employees had an identical median of 1990 for this question in a pre-test. A 1963 study conducted four years earlier of when controlled fusion would be achieved had a median of 1986. For the example given above, the median of the eight individuals who ranked themselves most expert had a median of 1987½. This figure, incidentally, was interpreted as the group response for this study.

Analysis of Example

This example provides an excellent vehicle for

further analysis of the Delphi procedure. The three characteristics of Delphi can now be evaluated relative to the usual shortcomings of group intuitive judgments. Following this, several other interesting observations can be made.

As previously stated, the basic characteristics of Delphi are anonymity, controlled feedback, and statistical group response. These features are intended to overcome the drawbacks of conventionally structured groups. To repeat, these faults are the influence of the dominant individual, noise, and the group pressure for conformity.

Anonymity does not necessarily mean that participants are unknown to each other. Rather, it means that a participant's response and arguments are known only to the administrator of the group and are not attributed to the individual. Anonymity, in conjunction with controlled feedback and statistical response, eliminates the influence of the dominant individual and reduces both noise and the pressure for conformity. The dominant individual can communicate only through statistical feedback and the optional arguments which are filtered through the administrator. A skillful administrator removes all evidences of status, verbosity, emotionalism, and pure speculation before feeding back the arguments. The dominant

individual no longer has a means to influence others by loudness, forceful personality, status, or talkativeness. In the process, noise, which is irrelevant or redundant information, is also largely eliminated. Anonymity, although not completely removing the group pressure for conformity, reduces this pressure because nonconformists are not identified. While there is an attraction of the group position which varies between individuals, this attraction is at least partially a result of weak convictions and is not completely undesirable.

Controlled feedback is also designed to help overcome all three faults of a discussion group. The extent to which this is successful depends upon the skill and impartiality of the administrator in preparing the arguments for feedback. In the given example, the arguments that the next drought would be world-wide and that nuclear fusion power was impossible were speculative and perhaps emotional. As such, they constituted noise and perhaps an attempt by an individual to dominate the results or pressure the group and should therefore have been eliminated. Feedback does not necessarily always include arguments and may consist only of the median and some measure of dispersion, usually taken as the IQR. The number of rounds may also vary from two to six. The purpose of feedback, besides preventing direct communications, is to

provide new information and to cause rethinking of the problem. In this way, the feedback in Delphi is used to preserve at least some of the interaction which is theoretically found in the usual group situation.

Statistical group response is used primarily to arrive at a consensus while preventing group pressure for conformity. In the usual discussion group, a high value is placed on agreement because of time delays and resentment which otherwise result. In a Delphi group, the group arrives at a judgment regardless of whether or not agreement occurs. Although pressure for conformity still operates with Delphi, this pressure is reduced to an internal and individual pressure.

The statistical group response consists of the median and to a lesser extent the IQR. The median is used rather than the mean because every individual's opinion is reflected in the final result, yet no individual can affect the final result by a deliberately extreme answer which would be possible if the mean were used. The IQR is also part of the group judgment because it provides the user of the judgment with some idea of the range within which an uncertain event is forecasted to occur. In the example, the degree of convergence is less than is usually obtained for a factual judgment of this type, indicating

a high degree of uncertainty.

The type and the form of the question in the example provides additional useful insight. The question being asked was highly appropriate for Delphi in that it contained a large degree of opinion. No amount of fact-gathering could have conclusively answered the question. On the other hand, the question was confusing because it really contained at least two questions. The question asked when power generated by thermonuclear fusion would be possible and also asked when it would be commercially competitive. To some people, a value judgment may also have been implicit in that they perhaps did not agree with the implied assumption that development of nuclear fusion power is desirable. There was also some confusion between nuclear fusion and nuclear fission which is apparent from the second round arguments. However, this confusion demonstrates the utility of the arguments to a user of the judgment. The irrelevant arguments indicate a lack of expertise among at least part of the group.

Although the group response was taken as the judgment of the subgroup who rated themselves most expert, any practical application of Delphi might benefit from a listing of the participants and their qualifications. In this way, the user of the judgment could judge for himself

the expertness of the group. A potential for discontent among the remainder of the group exists if the practice of selecting the most expert subgroup is regularly followed.

As noted before, the user can judge the group's expertise or lack of it by examining the group's arguments. Perhaps he can spot arguments he considers vital which have been overlooked. Even if he does reject the judgment of the group, he often gains considerations and insight into the problem which he might have overlooked by himself.

This example used conference participants in which the entire Delphi process was finished in a single day. Usually, the questionnaire is mailed with a period of several weeks between the beginning and the end. With the longer elapsed time, the process of rethinking is more important and individuals may research isolated facts between rounds and bring them to the attention of the group.

The question which was asked required a forecast of a single number. If, instead, a value judgment is needed, such as a judgment as to the desirability of the development of thermonuclear fusion power, a scale can be set up for participants to indicate their value judgment. This scale could run from one through five with

appropriate definitions of each value. Another possible application is the choice between alternatives, in which the relative desirability of each alternative can be indicated. Many other applications are possible, some of which will be referenced later.

Experimental Results

The concern up to this point has been to obtain a knowledge of the workings of Delphi and a subjective feeling for the potential features of Delphi. Surprisingly, the properties of Delphi can be placed on a much more objective basis. To this end, a large number of experimental studies have been performed, primarily at RAND Corporation. Almanac-type questions were used for these experiments in order to have questions with a high opinion content but with verifiable but obscure answers. In the most comprehensive of these studies, college students were used to provide about 13,000 answers to 350 questions in 10 different experiments.⁶ Unless otherwise indicated, results in this section are taken from this major study. This study is fully documented in a companion reference, including the structure of the experiments, the questions, and the responses.⁷

In these experiments, the group error was defined as the absolute value of the logarithm of the ratio of

the group median and the true answer. Thus, if the median is .001 or 1000 when the true answer is 1, the group error is 3. If the median is equal to the true answer, the group error is zero. The group error was defined in such a manner because the nature of the questions was such that the estimates and true answers sometimes differed by a factor of 10,000.

These experiments were able to show how the average group error decreased with increasing group size. For example, a group size of 6 had an average group error of .63 while a group size of 29 had an average group error of .44. The ability of different but equal-sized groups to produce similar results is also highly related to group size. The reassuring ability of different groups to produce similar forecasts has also been noted in several practical applications.⁸

Other experiments compared the performance of discussion groups with Delphi groups. While answering the same questions, Delphi groups were more accurate than discussion groups in 13 out of 20 cases. Also, while using the Delphi method between rounds one and two and using discussion between rounds two and three, the average improvement towards the true answer was better with Delphi than with discussion groups. In general, Delphi held a

definite advantage over discussion groups, substantiating the basic presumption of its usefulness.

While investigating the iterative feature of Delphi, it was found that improvement of answers between subsequent rounds occurred in 64% of the cases and that degradation of answers occurred in the remaining 36% of the cases. Decreases in accuracy did not exceed the increases in accuracy in any of the 11 groups used. The basic conclusion that improvement occurs with later rounds was statistically significant with a confidence level of 99%.

The mechanism of improvement was also a matter of concern. The distribution of the individual first round answers was found to be a log-normal distribution. Also, the average error on round one was linearly related to the dispersion, indicating that a correlation existed between the accuracy of the group's first round response and the spread of the responses. However, neither relationship was valid for later rounds, making it impossible to use only these two factors to attach a confidence level to the final result. The underlying reason for this result was that later responses, in addition to being attracted by the true answer, were also attracted through social pressure to the previous median. The attraction of the previous median was the dominant influence, destroying

the log-normal distribution and the correlation between average error and spread. Consequently, the convergence or decreased IQR on the second and later rounds implies an accuracy or confidence which is not warranted.

Some persons termed as holdouts tended to retain their initial estimates on later rounds while others identified as swingers tended to freely change their estimates. Both types were useful. The holdouts were more accurate in the first round, but in round two the total group was more accurate than the holdouts because of the effect of the swingers. This result occurs because in order for any desired improvement to occur, some members of the group must cross to the opposite side of the previous median.

The effect of various aspects of an expert's qualifications was also analyzed. Women were initially less accurate but were more changeable and therefore significantly improved the later round results. Surprisingly, students of the soft sciences were found to be more adept at initial estimates than students with a background in the physical sciences. In neither situation were the final results significantly affected by shortcomings in initial rounds. Also, no relationship between average group intelligence and group performance existed. The conclusion was

reached that the standards commonly used for selection of experts concerning knowledge are not necessarily valid for selecting experts to deal with opinion.⁹

In another experiment, different time intervals ranging from 15 seconds to 4 minutes were allowed for forming estimates. Even while answering complex questions with a high degree of opinion, optimum estimates were obtained when only 30 seconds were allowed.

In a different study, the use of self-ratings was questioned.¹⁰ Self-ratings were found to be useful in substantially improving the accuracy of a group by selecting a sub-group of experts based on these ratings. Two conditions were necessary for this improvement. The first was that the sub-groups of both the experts and non-experts must be sufficiently large, taken as seven in this study. Also, the self-ratings must differ considerably between the two sub-groups. The example required the self-ratings of all members of each sub-group to differ from the opposite group by at least one point on a five point rating scale. The average self-rating of a group along with the dispersion of the group's answers was found to be related to the mean accuracy of the group response. This result holds forth the possibility of eventually attaching error estimates to the results.

The question of improving the feedback was the exclusive concern of another study.¹¹ Two types of feedback were compared with the usual type of feedback. In one variation, each person was fed back the percentile location of his answer. No differences were noted between this feedback and the usual procedure. The study concluded that Delphi is not sensitive to the form of the numerical feedback so long as it accurately summarizes the group position. In another variation, the effect of providing an additional obscurely related fact was studied. A decisive improvement was noted, suggesting an ability of the human mind to effectively utilize bits of information. One or two additional facts improve accuracy, but more facts may cause saturation and may change the nature of Delphi completely.

The question of the validity of using almanac-type questions for obtaining the previous experimental results has also been addressed.¹² Almanac-type questions were compared with short-range predictive questions for which the answers would be known in the near future. A typical predictive question concerned the total number of a certain kind of car which would be produced in the next year. The two types of questions being compared contained a similar amount of opinion. The improvement between rounds was

comparable for the two types of questions. However, the accuracy of the predictive questions was generally better than for the almanac-type questions; a result attributed by the researchers to the presumption that the participants felt that the predictive questions were more meaningful. The validity of Delphi forecasts is also addressed in a 1970 evaluation of a 1964 forecast.¹³ Of 13 events concerning space progress whose median forecast date was 1970 or earlier, 6 events had occurred by 1970.

All experimental results cited to this point have concerned themselves with factual judgments. Another experiment has been performed to compare Delphi value judgments with factual judgments.¹⁴ The goal of this study was to generate and rank values associated with both higher education and the quality of life. The structure of the experiment exemplifies the adaptability of Delphi. Initially, the 80 participants were divided into two groups and asked to list important contributing factors for the two topics. To make the resulting lists of 250 and 300 items more manageable, all possible pairs of items were then rated by the groups for similarity. These ratings enabled the lists to be reduced to 45 and 48 items. Next, the groups were asked to rate the relative importance of each item on the lists. This rating was then

iterated after feeding back the previous medians and quartiles. Finally, the groups rated the relative contribution of each item on the education list to items on the quality of life list. Although the correctness of value judgments cannot be judged, other comparisons with factual judgments were made. As for factual judgments, the distribution of answers was nearly always single peaked and bell-shaped. The correlations between groups, the number of changes, and the convergence were also comparable to results for factual material. In general, Delphi proved to be appropriate for value judgments, although the dispersion was about twice as great as it is for factual material. As a sidelight, different methods and scales for indicating the relative importance of items gave no significant differences in the final result.

Precautions

Many persons have found the idea of a Delphi study to be appealing and have later discovered that the process is not as simple as it appears. This section attempts to summarize the practical difficulties involved in using Delphi. With prior knowledge, the difficulties of administration, the selection of experts, and the interpretation

of results are not insurmountable and are largely avoidable.

The administrator of Delphi must be extremely careful in formulating the questionnaire.¹⁵ Compound questions and loosely defined, imprecise, or ambiguous wording must be avoided. Debatable assumptions must not be imbedded within the questions. The time required to complete a questionnaire is easily underestimated. If arguments are fed back, the arguments must be summarized fairly.

Another study suggests that a shakedown trial be used to identify possible misunderstandings within the questionnaire.¹⁶ Questionnaires should ask direct questions only and not those which require essay answers. To handle the large amount of data which may be generated in some studies, the questions should be formulated so that the analysis can be computerized.

In a critique of a major study directed at examining civil defense policy, one of the co-inventors of Delphi made many useful comments.¹⁷ Binary type questions should be avoided or rephrased so that more than two responses are permitted. No useful interpretation is possible and effort is wasted in the event of disagreement on binary questions. In general, wide dispersion of responses should not be interpreted as disagreement, but is probably more often a lack of information. When feeding back arguments,

supplementary material will tend to be biased and highly opinionated if the volume is not limited. In later rounds, the amount of this material should be reduced by consolidating the arguments. The arguments when properly used should be suggestive and are not intended to present the full complexity of the problem. Instead, the complexity should remain internalized within the minds of the participants. Delphi should be used to construct a model through which the full complexity of the problem can be explored by other methods if this complexity is needed.

There is also a legal difficulty when Delphi is used by government agencies.¹⁸ An Act of Congress (5 USC Sec. 139, c-e, 1942) prohibits government agencies from mailing more than nine identically worded questionnaires to private agencies without Bureau of the Budget approval. Since the purpose of the law is to prevent indiscriminant bothering of businessmen, approval should be easy to obtain. Otherwise, up to nine outside participants could be used in conjunction with any number of governmental participants. This reference also cautions that Delphi is not a substitute for research, but rather is properly used only for situations when research is impossible.

Another precaution concerns itself with the proper selection of experts. An example is given of a long-range

forecasting study using Delphi which addressed the question of ocean farming.¹⁹ The productivity of the ocean was overestimated, practical problems involving ocean farming were underestimated, alternatives were overlooked, and international legal complications were ignored. The panel addressing this question consisted primarily of persons with physical science and engineering backgrounds without any political, biological, or legal representation. Major aspects of the problem were overlooked, and the forecast was probably overly optimistic because certain types of expertise were not represented.

Advantages

Much of what has been written has already addressed the advantages of Delphi. However, there are additional advantages which have not been treated and some advantages have only been alluded to.

The adaptability of Delphi has already been mentioned. Studies are in progress which mix other approaches with Delphi to make better use of each method's advantages.²⁰ For example, when participants are used to generate the study material, Delphi approximates the creativity and techniques of brainstorming. Gaming also lends itself to use with Delphi. Simulation is especially useful in forcing Delphi participants to be realistic, as in simulated

budget planning exercises.²¹

One of the major advantages at the industrial level is the feeling of involvement which participants gain in a Delphi exercise and which orients a staff toward future planning and future possibilities.²² Other advantages are a feeling of shared responsibility which releases inhibitions.²³ Delphi is novel and interesting, leading to better group motivation and an air of objectivity provides a greater group acceptance. Little manpower is required and travel is eliminated. Questionnaires can be answered in unscheduled time and take much less time than a conference.

Disadvantages

In contrast with the advantages, the disadvantages of Delphi have been treated very lightly in previous parts of this study. Some of the disadvantages are almost obvious, but will be mentioned briefly for the sake of completeness.

Obviously, Delphi is cumbersome with long time delays and with the danger of forgetting prior responses in later rounds.²⁴ Most practical studies using mailed questionnaires have found it necessary to allow about two weeks for each round. For long studies, the analysis can also be time consuming unless it is computerized. Arguments, if properly

edited, will always be time consuming. Also, Delphi has only limited ability to give extra weight to outstanding expertise or to critical areas of expertise.

The use of Delphi, in addition to being time consuming, can be expensive if a large group of consultants is used.²⁵ The success of Delphi is highly dependent on the skill of the administrator, the climate, and the proper selection of experts. Even in a creative atmosphere, it is possible to completely overlook important items for investigation. Also, Delphi is open to various misuses depending upon the integrity of the administrator and the organization.²⁶

From an analytical forecaster's viewpoint, Delphi is sometimes mistrusted because the quantitative appearance of Delphi might be misinterpreted by laymen.²⁷ Also, some questions are not simple enough to be adequately answered by a simple response.²⁸ When used as an exploratory forecasting tool, another expert feels that Delphi is not useful because each respondent answers the questions based on a different set of assumptions.²⁹ For example, when estimating the date when a certain technological development will occur, it is necessary to assume when other related precursor developments will occur. Another expert reinforces this view by pointing out that the inter-

relationships of events are completely ignored by Delphi.³⁰ Future events are, however, often related to one another. If one event occurs, the probability of the occurrence of another related event may be either increased or decreased. With Delphi, each event is considered independently and the final results may lack self-consistency. A method has been developed to mathematically make corrections to Delphi forecasts so that the cross-correlations are self-consistent.³¹ However, the method is mechanically applied after the fact instead of being a part of the forecast.

Variations of Delphi

Some variations of Delphi have been developed with the specific aim of removing some of the disadvantages of Delphi. Only two major variations of Delphi are considered here. Minor variations in the number of rounds, the type of feedback, and similar changes in the structure of Delphi have been treated elsewhere.

While at the Air Force Systems Command, Howard A. Wells developed a system of electronic voting to remove some of the cumbersome aspects of Delphi while retaining its anonymity.³² Members of a group gather in a conference room and each person votes by secretly positioning a rotary switch which turns on a light in his column of

lights. Everyone is aware of the group position because all lights are visible although no individual is identified with any particular vote. After the first vote, open discussion is held, followed by a second secret vote. The standard deviation is automatically calculated after the second vote and all votes outside of one standard deviation are rejected. The group judgment is taken as the arithmetic mean of the remaining votes.

It has been suggested that the Wells system might be improved by altering voices electronically during discussions or by passing written comments to the administrator in order to preserve anonymity during the discussion phase.³³

Another variation of Delphi is the Delphi Conference which has been investigated by the Office of Emergency Preparedness as a means of obtaining rapid advice from widely scattered experts during emergency situations.³⁴ Instead of using questionnaires, the Delphi Conference uses a computer connected by ordinary telephone wires to a teletype machine located in the office of the respondent. The usual Delphi structure is used except that there is usually no rigid adherence to the round structure. Costs are drastically lowered. During a 13 week experiment with 20 respondents, a total of 100 hours of terminal

time and 1 hour of processor time was used for a total computer cost of \$1500. Some participants felt that the Delphi Conference was a mechanism which was designed to avoid the cost of normal consulting fees.

One observer feels that the future growth of Delphi depends upon a more extensive use of the computer.³⁵ For example, cross-correlation of events could be made self-consistent while the Delphi Conference is in progress. The Delphi Conference could also provide a learning experience for the participant. The Institute for the Future has developed a computer network of experts to perform a Delphi study quickly.³⁶ The suggestion has been made that the Air University should form a similar network to utilize the expertise of past graduates to solve problems.³⁷ Such studies would benefit students assisting in the administration of the studies and have been proposed as a replacement for the present research papers which often do not address or solve a practical problem.

CHAPTER IV

APPLICATIONS OF DELPHI

This chapter provides a survey of some of the practical applications of Delphi. This survey does not specifically focus upon the results of the studies nor does it pretend to be complete, but rather it attempts to indicate the various types of applications and the extent of usage of Delphi. For purposes of comparison, the applications have been separated into those made by industry, DOD, other agencies and the Soviet Union. The dividing line between practical and experimental applications is a fine line because the method is so new. Thus, in some cases the line is drawn rather arbitrarily.

Industrial Applications of Delphi

The first major industrial application of Delphi was made by TRW in 1966.¹ All units of the company were represented by 27 technical experts in this exercise, called Probe I. These experts were asked to identify and forecast the date of occurrence of technical events which would have a major impact on TRW over a 20 year period.

A list of 401 events was organized and analyzed.

To expand the scope of Probe I and clarify a few contradictions, Probe II was organized and completed in 1968. In this study, 140 in-house participants were used to compile a list of 1750 events which were then rated according to desirability, feasibility, and timing.² Incidentally, one of the administrators has since indicated that future studies of this type would not be restricted to in-house personnel.³

Probe II was the most massive study undertaken up to that time. To handle the large volume of data, computers were used with on-line terminals. The computer was programmed to present only those questions pertaining to an individual's expertise.⁴ This exercise differed from the Delphi Conference only by the retention of the discrete round structure.

An additional technique was used after the forecast to analyze the results. This technique used Sequence of Opportunities and Negatives (SOON) charts to depict existing technology which would be negated by a new development and also to depict alternate developments which would be required to achieve a final development.⁵ Fruitful areas of research were considered to be intermediate technologies which were prerequisites to several final developments. As

in many other industrial applications, most of the information derived from this study is considered proprietary information and has not been released.

In an article which indicates that many firms reduced their forecasting staffs during the 1970 recession, several other applications of Delphi in industry are indicated.⁶ General Dynamics has used Delphi groups to provide information in the form of forecasts concerning fluidics, non-destructive testing of composite materials, and laser developments. In order to predict future markets, Bell Canada has used Delphi to determine the future of educational, medical, and information-processing technology.

Project Aware is a Delphi study being undertaken at the Institute for the Future which is being funded by four large companies--Du Pont, Scott Paper, Monsanto, and Lever Bros.--at a cost of \$40,000 each for the next three years.⁷ This study is concerned with the social, economic, and technological trends over the next ten years.

Other major companies which have used Delphi include Sandia Corporation, Xerox, Chase Manhattan, Ling Temco Vought, and McDonnell Douglas.⁸ In 1968, well over 100 studies were estimated to be planned or in various stages, many of which were undoubtedly industrial applications.⁹ As indicated by the examples, these industrial Delphi

applications were forecasts (largely technological) to be used as a basis for corporate planning.

Defense Department Applications

The Defense Department and particularly the Air Force has directly sponsored much of the experimental study of Delphi performed at RAND. The two agencies which have been most active in the sponsorship of this work are the Advanced Research Projects Agency and Hq, USAF. Pilot studies have also been performed at the Office of Aerospace Research and the Defense Intelligence Agency.¹⁰ In spite of this apparent interest, only four applications of Delphi either by or for the Defense Department have been discovered.

The first known usage of Delphi of any type was performed in 1953 by RAND. This study was also the first known Delphi publication when it was published after declassification ten years later. Performed under the sponsorship of the US Air Force, this study addressed the question of the number of enemy nuclear weapons which would be required to reduce the US industrial capacity by a stated amount.¹¹ Some facts were supplied by the administrators and the respondents also performed independent research during the study to determine the vulnerability of different industries. The contents of this

study are still interesting from a military viewpoint 20 years later.

Another application of Delphi has been made to determine considerations for the future logistics base of the US Army.¹² The scope of this project was extremely broad. An evaluation of past Army logistics was performed, the threat and the technology of the next 15 years were forecasted, and the Army size, skills, construction needs, and mobilization ability were projected. Overall, the study was considered useful for suggesting future trends and providing insight into the future of the Army. However, a need for procedures to speed up the entire Delphi process was identified.

A brief reference to a Delphi study performed as a small part of the first Navy technological forecast was also found.¹³ Only 5% of the total forecasting effort was of an intuitive nature; 80% of the \$1.9 million forecast consisted of trend extrapolation. No other details of this single Delphi examination were given.

The final example of the application of Delphi by DOD was a 1970 study funded by ARPA.¹⁴ Civil defense was examined relative to strategic issues, future strategic systems, arms limitations, international problems, and domestic programs. In addition to the broad scope of

questions, significant innovations were employed. A typical question was, "Assured destruction (should/should not) remain our primary strategic concept." In addition to indicating the answer, the respondent indicated a self-rating and an importance rating for each question. Thus, the desirability and feasibility were at least partially separated and the results were plotted as a point on a graph with each of the axis representing one of these quantities. At the end of the exercise, the respondents were asked to write a short essay on their opinions concerning civil defense. These essays were included as part of the results.

Delphi Applications by Other Agencies

The extent to which Delphi is employed by other agencies can be deduced by a survey of all futures research performed by all methods.¹⁵ This survey showed that Delphi was the second most frequently used method. Delphi was used nearly as often as scenario building and considerably more than simulation and gaming, the third most frequently used method. In addition to industry and DOD, the types of other agencies which performed futures research included nonprofit organizations, educational institutions, other Federal government agencies, state and regional commissions, religious organizations, and

professional, business, and academic associations. The primary topics of this research were technological and economic forecasting. The remaining topics ranged widely and comprised (as a partial list) environment, population, public affairs, resources, biology, leisure, life extension, medicine, psychiatry, race relations, sex education, and regional development. While Delphi might not have been used to consider each of these topics because the survey did not provide a breakdown by forecasting method, Delphi must nevertheless be recognized as a widely used forecasting method.

Perhaps a few of the numerous available examples will further illustrate the widespread usage of Delphi. In 1968, a technological forecast of computer developments was prepared with two rounds in 25 days using 88 participants.¹⁶ This forecast was used as the basis for discussion at an international conference of computer experts. Some of the attendees at the conference were also the experts used in the preparation of the forecast.

As another example, a Delphi forecast of the future of education was prepared during an educational conference.¹⁷ The topics were drawn from a wide range of sources such as a literature search, conference papers, student essays, seminar proceedings, and the first Delphi questionnaire.

After identifying those aspects of education which deserved attention in the early rounds, the final round consisted of a simulated budget process. Each member was provided a budget and the approximate cost of each item and asked to allocate the budget among the items. The extra realism of the simulation was judged to be worthwhile by both the administrators and the participants.

Another quite common use of Delphi is a questionnaire which is inserted in professional journals to obtain the response of the readers. An example of this is given in an article which gave the results of an investigation into future changes in management using top management professors as participants. Readers were urged to expand the scope of this study by responding to a similar questionnaire.¹⁸

Generally, the nature of these Delphi studies differs somewhat from those of industry and DOD. Industry and particularly DOD Delphi studies are apt to be broader in scope and more practical in purpose. In addition, the studies of other agencies tend to be partial substitutes for other research and are also more speculative.

Delphi Within the Soviet Union

The question of the acceptance of Delphi within the Soviet Union is particularly interesting in the context of

their need for future planning. The idea is commonly accepted that their economic system requires more planning when compared with the capitalist system in which economic regulation is done by prices within the market.

Only a partial answer can be given to this question. One review states that Soviet literature implies that the Delphi technique has been used. Overall, Soviet forecasters are highly familiar with Western techniques.¹⁹

A different review of Soviet literature states that the Delphi technique has been extensively used.²⁰ Delphi is considered to be the most sophisticated of the intuitive methods and is used much as in the United States. One Soviet author lists five necessary conditions for the effective use of Delphi: mutual independence of judgments (anonymity), quantitative form of evaluation (statistical response), the explicit formulation of arguments, self-ratings, and constructive attitude.

The Soviets have developed a technique similar to the SOON charts previously mentioned to be used in conjunction with the Delphi forecasts. This is a goal-means matrix showing all of the potential paths for achieving a final goal. To decide upon the most feasible means, participants are asked to evaluate the relative importance of each means, the length of time required, the importance

of any problems to be encountered, and the importance of arguments which are presented. Generally, technological forecasting is accepted at the highest level of Soviet government, unlike the US.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The substantial although admittedly incomplete evidence of the previous chapter prompts the conclusion that DOD has lagged considerably behind industry and other agencies in the adoption of the Delphi method. This chapter provides some reasons for DOD's reluctance to use Delphi, focusing particularly upon its seemingly attractive applications for technological forecasting. After this, some conclusions are offered concerning other potential applications of Delphi. Finally, some recommendations are made concerning the utilization of Delphi within DOD.

Part of DOD's relative disinterest in Delphi as compared to industry can be explained by a changing emphasis on technological forecasting within DOD. In the past, the purpose of technological forecasting within DOD has been to identify developments which were technically possible.¹ This objective was determined by the prevailing assumption of DOD decision makers that any developments which were both feasible and useful would be

developed by the enemy and therefore should also be developed by the US. The nature of these past policies is reflected by some research which explored possibilities with no known utility but which might prove useful at some future time.

These concepts have changed drastically. Costs have become just as important as weapon system performance and development time. In order to control costs, it is often necessary to accept decreased performance by rejecting unproven and risky technology. An alternative is to stretch-out the development time to allow additional time to first obtain a better understanding of a new technology. The new policy is closely aligned with the conclusion of a major study which determined that research breakthroughs almost invariably resulted from research which was directed toward a specific need.² The new attitude is also exemplified by prototype competitions and fly-before-buy programs.

These changes in DOD's research and development policies have many implications for technological forecasting. These policies have decreased the DOD usage of technological forecasting. In the past, widespread usage was necessary to identify all developments which were technically possible. Technological forecasting is

now used to develop alternatives only for those weapon systems for which a definite need exists and to select the most cost-effective of these alternatives. On the other hand, many segments of industry have discovered technological forecasting for the first time within the past ten years and its role in industry has greatly expanded within this period.

The increased emphasis on controlled costs in the new DOD policies places a premium on proven technology. When well-understood technologies are employed, the existing data base makes the use of quantitative forecasting methods desirable. At the same time, the increased understanding makes a choice of intuitive methods in general and Delphi in particular less suitable.

Apart from the new DOD policies, there are other factors which make Delphi less suitable for DOD than for industry. DOD organizations possess considerable experience and skill in applying quantitative forecasting methods and have accumulated vast data bases for use with these methods. By comparison, most industries are relatively new to forecasting and must necessarily rely to a greater extent on comparatively simple forecasting techniques such as Delphi.

Delphi is also somewhat more suitable for industrial

forecasting because of the purposes of industry. Instead of being needs-oriented as in DOD, technological forecasting within industry tends to be opportunity-oriented. Only one or a few new possibilities which satisfy corporate goals need be identified. The enhancement of creativity by Delphi makes it suitable for this purpose. In addition, the success of a new product depends to a great extent upon the reactions of competitors and the potential market demand for the new product. These considerations are mainly of an intuitive nature, further enhancing Delphi's suitability.³

The organizational structure of DOD further tends to make a choice of Delphi less likely than for industry. Any technical proposal must pass through several levels of decision makers before obtaining final acceptance. Each of these higher headquarters must be convinced by rational, explicit, and insofar as possible, quantitative arguments.⁴ Failure to provide acceptable arguments will delay the proposal until it is cancelled. The decision maker cannot make the decision based on intuition because the complexity of modern weapon systems exceeds his ability to understand the broad array of technology involved. For this reason, he cannot judge the value of a Delphi study which is performed by unknown persons at lower levels and

therefore tends to reject it.

In a typical industrial unit, however, the technological forecasting unit is on a level which is at or near the decision makers. Proposals can and generally will be limited to familiar technology. These factors make Delphi more acceptable to industry.

All of these factors which have been enumerated provide reasons why Delphi has gained a better acceptance for technological forecasting within industry than within DOD. The question remains as to whether or not there are other advantageous applications within DOD.

The previous arguments have dealt mainly with forecasting technology to be used for specific applications in new weapon systems. A potential does exist, however, for Delphi's application for exploratory forecasting of technology. If new weapon systems increasingly rely on proven technology, but if at the same time technology is not to come to a standstill, forecasting must identify research possibilities which have future although as yet unspecified usefulness. Because these decisions are generally made at a lower level, creativity is required, and a high degree of opinion is present; Delphi would appear to meet the requirements for this task.

There are probably other situations in which Delphi

could be used to advantage. Certainly, intuitive judgments are frequently used in DOD. Consider promotion boards as a specific example. Promotions should be based on the "whole man concept," which really means that promotion boards make their intuitive decisions based on the fragmentary evidence of a person's records. The definition of the future environment or threat analysis also involves a high degree of speculation. The tendency is to use group decisions in this type of situation; yet, Delphi possesses advantages over the usual group decision and probably should be used in some applications.

Whether or not Delphi can profitably be employed depends upon specific circumstances and situations. Each Service might assign an appropriate agency to investigate potential applications of Delphi. However, a directive indicating where Delphi should be used would probably be harmful. Delphi is merely another tool which will be beneficial only when properly used.

Several other conclusions can be derived from this report. Foremost among these conclusions is that Delphi is not simply a set of procedures. An inexperienced administrator or an improper selection of experts can destroy the effectiveness of a Delphi study. The administrator must understand much of the material presented in

the previous chapters if he is to select the proper situation for Delphi's use and if he is to properly manage the study.

DOD must begin to educate its managers if the potential benefits of Delphi are to be realized. This education could easily be incorporated into the Professional Service Schools and perhaps into other specialized schools as well. A good understanding and an acceptance of the method could be acquired with very little instruction and could be added to existing blocks of instruction regarding group dynamics.

Finally, further research should be performed concerning the feasibility of the Delphi Conference for DOD applications. This would overcome the main objection to Delphi--the long period of time required to accomplish a study. The widespread usage of computers and the excellent communications networks would seem to make DOD the ideal candidate for the use of the Delphi Conference.

FOOTNOTES

Chapter I

1. Olaf Helmer, Analysis of the Future: The Delphi Method, RAND Report P-3558, Santa Monica, Calif., March 1967, pp. 1-3.
2. Ibid., pp. 8-9.

Chapter II

1. Norman C. Dalkey, Predicting the Future, RAND Report P-3948, Santa Monica, Calif., October 1968, p. 5.
2. Ibid., p. 3.
3. Ibid.
4. Norman C. Dalkey, Delphi, RAND Report P-3704, Santa Monica, Calif., October 1967, p. 2.
5. Robert U. Ayres, Technological Forecasting and Long-Range Planning (New York: McGraw Hill Book Company, 1969), p. 143.
6. N. Dalkey, B. Brown, and S. Cochran, The Delphi Method, IV: Effect of Percentile Feedback and Feed-In of Relevant Facts, RAND Memorandum RM-6118-PR, Santa Monica, Calif., March 1970, p. 28.
7. Nicholas Rescher, Delphi and Values, RAND Report P-4182, Santa Monica, Calif., September 1969, p. 3.
8. Ibid., p. 11.
9. Norman C. Dalkey and Daniel L. Rourke, Experimental Assessment of Delphi Procedures with Group Value Judgments, RAND Report R-612-ARPA, Santa Monica, Calif., February 1971, p. iv.

10. E. S. Guade and W. I. Boucher (eds.), Systems Analysis and Policy Planning: Applications in Defense (New York: American Elsevier Publishing Company, 1968), p. 325.

11. Ayres, op. cit., p. 33.

12. Helmer, Analysis of the future: The Delphi Method, p. 1.

13. Bertrand de Jouvenal, in Foreword to Technological Planning and Social Futures, by Erich Jantsch (New York: John Wiley and Sons, 1972), p. xiii.

14. Colonel Joseph P. Martino, Opening Remarks, Long-Range Forecasting and Planning, A Symposium held at the US Air Force Academy, Colo., 16-17 August 1966, Defense Documentation Center, Alexandria, Va., p. 2.

15. Helmer, Analysis of the Future: The Delphi Method, p. 3.

16. "Updating the Crystal Ball," Newsweek, November 26, 1973, pp. 101-102.

17. Erich Jantsch, Technological Planning and Social Futures (New York: John Wiley and Sons, 1972), p. 162.

18. Ayres, op. cit., pp. 72-159.

19. Nicholas Rescher, The Future as an Object of Research, RAND Report P-3593, Santa Monica, Calif., April 1967, p. 5.

20. Ayres, op. cit., p. 72.

21. Ibid., pp. 94-100.

22. Ibid., pp. 118-141.

23. Ibid., pp. 145-146.

24. Olaf Helmer, Comments from Long-Range Forecasting and Planning, p. 92.

25. T. J. Gordon, "New Approaches to Delphi," Technological Forecasting for Industry and Government, ed. James R. Bright (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1968), p. 134.

26. John C. Chambers, Satinder K. Mullich and Donald D. Smith, "How to Choose the Right Forecasting Technique," Harvard Business Review, Vol. 49, No. 4, pp. 45-50.

27. Ayres, op. cit., p. 144.

28. Dalkey, Predicting the Future, p. 7.

29. Norman C. Dalkey, The Delphi Method: An Experimental Study of Group Opinion, RAND Memorandum RM-5888-PR, Santa Monica, Calif., June 1969, p. 6-8.

Chapter III

1. Dalkey, Predicting the Future, p. 8.

2. Dalkey, Delphi, p. 3.

3. James R. Bright (ed.), Technological Forecasting for Industry and Government, (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1968), p. 123-133.

4. Ibid., pp. 128-129.

5. Ibid., pp. 130-131.

6. Norman C. Dalkey, The Delphi Method: An Experimental Study of Group Opinion, pp. 1-78.

7. B. Brown, S. Cochran, and N. Dalkey, The Delphi Method, II: Structure of Experiments, RAND Memorandum RM-5957-PR, Santa Monica, Calif., June 1969, pp. 1-99.

8. Colonel Joseph P. Martino, "The Consistency of Delphi Forecasts," The Futurist, Vol. IV, No. 2, April 1970, pp. 63-64.

9. Dalkey, Predicting the Future, p. 17.

10. N. Dalkey, B. Brown, and S. Cochran, The Delphi Method, III: Use of Self-Ratings to Improve Group Estimates, RAND Memorandum RM-6115-PR, Santa Monica, Calif., November 1969, pp. 1-19.

11. Dalkey, Brown, and Cochran, The Delphi Method, IV: Effect of Percentile Feedback and Feed-in of Relevant Facts, pp. 1-29.

12. N. Dalkey and B. Brown, Comparison of Group Judgment Techniques with Short-Range Predictions and Almanac Questions, RAND Report R-678-ARPA, Santa Monica, Calif., May 1971, pp. 1-20.

13. Roy C. Amara and Gerald R. Salancik, "Forecasting: From Conjectural Art Toward Science," The Futurist, Vol. VI, No. 3, June 1972, pp. 112-116.

14. Dalkey and Rourke, op. cit., pp. 1-42.

15. Colonel Joseph P. Martino, "An Experiment with the Delphi Technique for Long-Range Forecasting," IEEE Trans. on Engineering Management, Vol. EM 15, No. 3, September 1968, pp. 138-144.

16. Albert D. Tholin, et. al., A Forecast of Logistics Requirements, Research Analysis Corporation, RAC-TP-427, McLean, Va., June 1971, pp. 2-4.

17. Norman C. Dalkey, "Comments on Civil Defense Exercise," A Delphi Examination of Civil Defense, Part 1, Appendix A, RAND Memorandum RM-6247/1-ARPA, Santa Monica, Calif., May 1970, pp. 77-83.

18. Quade and Boucher, op. cit., p. 337.

19. Ayres, op. cit., pp. 150-153.

20. Gordon, op. cit., pp. 142-143.

21. Marvin Adelson, et. al., "Planning Education for the Future," American Behavioral Scientist, Vol. 10, No. 7, March 1967, pp. 1-31.

22. Jantsch, op. cit., p. 83.

23. Dalkey, The Delphi Method: An Experimental Study of Group Opinion, p. 17.

24. "Think Tank that Helps Companies Plan," Business Week, No. 2294, August 25, 1973, p. 71.

25. John P. Dory and Robert J. Lord, "Does Technological Forecasting Really Work," Harvard Business Review, Vol. 48, No. 6, November-December 1970, pp. 20-21.

26. Dalkey, The Delphi Method: An Experimental Study of Group Opinion, p. 17.

27. James E. Hacke, Jr., "A Methodological Preface to Technological Forecasting," Long-Range Forecasting and Planning, p. 49.

28. Captain James C. Van Pelt, USN, "Technological Forecasting: Approaches, Techniques, and Theory," Perspectives in Defense Management, January 1971, p. 51.

29. Jantsch, op. cit., p. 83.

30. Gordon, op. cit., p. 135.

31. Norman C. Dalkey, An Elementary Cross-Impact Model, RAND Report R-677-ARPA, Santa Monica, Calif., May 1971, pp. 1-5.

32. Howard A. Wells, "Weapon Systems Planner's Guide," Long-Range Forecasting and Planning, p. 62.

33. Ayres, op. cit., p. 156.

34. Murray Turoff, "The Delphi Conference," The Futurist, Vol. V, No. 2, April 1971, pp. 55-57.

35. George P. Mandanis, "The Future of the Delphi Technique," Technological Forecasting, R. V. Arnfield, (ed.), Edinburgh: Edinburgh University Press, 1969, pp. 164-165.

36. "Think Tank that Helps Companies Plan," Business Week, No. 2294, August 25, 1973, p. 71

37. Lieutenant Colonel Roger Budd, Jr., "Technology Unemployment," (Unpublished Air War College research report, Air University, Maxwell AFB, Alabama, 1972), pp. 24-28.

Chapter IV

1. Harper Q. North, and Donald L. Pyke, "Technology, the Chicken--Corporate Goals, the Egg," Technological Forecasting for Industry and Government, pp. 412-425.

2. Ayres, op. cit., pp. 153-156.
3. Donald L. Pyke, Comments in Approaches to Long-Range Forecasting, A Symposium held at Alamogordo, New Mexico, 29-30 April 1969, Government Printing Office, Washington, D. C., p. 75.
4. Colonel Joseph P. Martino, "Computers and Technological Forecasting," The Futurist, Vol. V, No. 5, October 1971, pp. 205-206.
5. Ayres, op. cit., p. 155.
6. Colonel Joseph P. Martino, "Technological Forecasting is Alive and Well in Industry," The Futurist, vol. VI, No. 4, August 1972, pp. 167-168.
7. "Think Tank that Helps Companies Plan," Business Week, No. 2294, August 25, 1973, p. 70.
8. Dalkey, Predicting the Future, p. 9.
9. Dalkey, The Delphi Method: An Experimental Study of Group Opinion, p. 15.
10. Ibid., p. 111. Also, Dalkey, Brown, and Cochran, The Delphi Method IV, p. 111.
11. N. Dalkey and O. Helmer, "An Experimental Application of the Delphi Method to the Use of Experts," Management Science, Vol. 9, No. 3, April 1963, pp. 458-467.
12. Tholin, op. cit., p. 3-4.
13. M. J. Cetron and D. N. Dick, "Producing the First Navy Technological Forecast," Approaches to Long-Range Forecasting, p. 78-85.
14. Edwin W. Paxson, A Delphi Examination of Civil Defense, Part I: Questions, Issues and Arguments, Part II: Tabulation and Analysis of Results, RAND Memorandum RM-6247-1-ARPA & RM-6247-2-ARPA, Santa Monica, Calif., May 1970, pp. 1-68.
15. "A Survey of Futures Research in the United States," The Futurist, Vol. IV, No. 6, December 1970, pp. 200-201.

16. Colonel Joseph P. Martino, "What Computers May Do Tomorrow," The Futurist, Vol. III, No. 5, October 1969, pp. 134-135.

17. Marvin Adelson, et. al., op. cit., pp. 1-31.

18. Robert W. Fulmer, "The Management of Tomorrow," Business Horizons, Vol. XV, No. 4, pp. 5-13.

19. Colonel Joseph P. Martino, "How the Soviets Forecast Technology," The Futurist, Vol. VII, No. 1, February 1973, pp. 30-31.

20. C. F. Woodhouse, Advanced Weapons Forecasting (Techniques and Applications), Report No. 1, Defense Intelligence Agency, Washington, D.C., March 1972, pp. 5-21.

Chapter V

1. Ayres, op. cit., p. 54.

2. Raymond S. Isenson, "Technological Forecasting Lessons from Project Hindsight," Technological Forecasting for Industry and Government, pp. 35-54.

3. Ayres, op. cit., p. 180.

4. James Bain, Jr., and Edward Shabsin, "Weapon System Planning," Defense Industrial Bulletin, Vol. 6, No. 7, July 1970.

BIBLIOGRAPHY

Books

Approaches to Long Range Forecasting. Proceedings of the Third Symposium on Long Range Forecasting and Planning held at Alamogordo, New Mexico, 29-30 April 1969, sponsored by the Office of Aerospace Research. Washington, D. C.: US Government Printing Office.

Arnfield, R. V. (ed.). Technological Forecasting. Edinburgh: Edinburgh University Press, 1969.

Ayres, Robert U. Technological Forecasting and Long-Range Planning. New York: McGraw Hill Book Company, 1969.

Bright, James R. (ed.). Technological Forecasting for Industry and Government, Methods and Applications. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1968.

Jantsch, Erich. Technological Planning and Social Futures. New York: John Wiley and Sons, 1972.

Long-Range Forecasting and Planning. Proceedings of a Symposium on Long-Range Forecasting and Planning held at the US Air Force Academy, Colo., 16-17 August 1966, sponsored by the Air Force Office of Scientific Research, Office of Research Analyses, and the Frank J. Seiler Laboratory. Springfield, Virginia: Clearinghouse, US Department of Commerce.

Quade, E.S. and Boucher, W. E. (eds.). Systems Analysis and Policy Planning: Applications in Defense. New York: American Elsevier Publishing Company, Inc., 1968.

Articles and Periodicals

Adelson, Marvin, Marvin Alkin, Charles Carey and Olaf

- Helmer. "Planning Education for the Future," American Behavioral Scientist, Vol. 10, No. 7 (March 1967), pp. 1-31.
- Amara, Roy C. and Salancik, Gerald R. "Forecasting: From Conjectural Art Toward Science," The Futurist, Vol. VI, No. 3 (June 1972), pp. 112-116.
- Bain, James Jr. and Edward Shabsin. "Weapon System Planning," Defense Industrial Bulletin, Vol. 6, No. 7 (July 1970).
- Chambers, John C., Satinder K. Mullich and Donald D. Smith. "How to Choose the Right Forecasting Technique," Harvard Business Review, Vol. 49, No. 4, pp. 45-74.
- Dalkey, Norman and Olaf Helmer. "An Experimental Application of the Delphi Method to the Use of Experts," Management Science, Vol. 9, No. 3 (April 1963), pp. 458-467.
- Dory, John P. and Robert J. Lord. "Does Technological Forecasting Really Work?" Harvard Business Review, Vol. 48, No. 6 (November-December 1970), pp. 16-28.
- Fulmer, Robert M. "The Management Tomorrow," Business Horizons, Vol. XV, No. 1, pp. 5-13.
- Fusfeld, Alan R. and Foster, Richard N. "The Delphi Technique: Survey and Comment," Business Horizons, June 1971, p. 64.
- Martino, Colonel Joseph P. "Computers and Technological Forecasting," The Futurist, Vol. V, No. 5 (October 1971), pp. 205-206.
- "An Experiment with the Delphi Method for Long-Range Forecasting," IEEE Transactions on Engineering Management, Vol. EM 15, No. 3 (September 1968), pp. 138-145.
- "The Consistency of Delphi Forecasts," The Futurist, Vol. IV, No. 2 (April 1970), pp. 63-64.
- "Forecasting the Progress of Technology," Air University Review, Vol. XX, No. 4 (March-April 1969), pp. 11-20.

- . "How the Soviets Forecast Technology,"
The Futurist, Vol. VII, No. 1 (February 1973),
pp. 30-31.
- . "Technological Forecasting in the US Air
Force," The Futurist, Vol. V, No. 6, (December
1971), pp. 251-252.
- . "Technological Forecasting is Alive and Well
in Industry," The Futurist, Vol. VI, No. 4
(August 1972), pp. 167-168.
- . "What Computers May do Tomorrow," The Futurist,
Vol. III, No. 5 (October 1969), pp. 134-135.
- "A Survey of Futures Research in the United States,"
The Futurist, Vol. IV, No. 6 (December 1970),
pp. 200-201.
- "Setting a Timetable," Business Week, No. 1677 (May 27,
1969), pp. 52-61.
- "Think Tank that Helps Companies Plan," Business Week,
No. 2294 (25 August 1973), pp. 70-71.
- Turoff, Murray. "The Delphi Conference," The Futurist,
Vol. V, No. 2 (April 1971), pp. 55-57.
- "Updating the Crystal Ball," Newsweek, 26 November 1973,
pp. 101-102.
- Van Pelt, Captain James C. (USN), "Technological Fore-
casting: Approaches, Techniques and Theory,"
Perspectives in Defense Management, January 1971,
pp. 47-56.

Official Documents

- Defense Intelligence Agency. Advanced Weapons Forecasting
(Techniques and Applications), Report No. 1, Washing-
ton, D.C., March 1972.
- Rand Corporation. Analysis of the Future: The Delphi
Method. Report P-3558, Santa Monica, Calif.,
March 1967.

- . Comparison of Group Judgment Techniques with Short-Range Predictions and Almanac Questions. Report R-678-ARPA, Santa Monica, Calif., May 1971.
- . Delphi. Report P-3704, Santa Monica, Calif., October 1967.
- . Delphi and Values. Report P-4812, Santa Monica, Calif., September 1969.
- . The Delphi Method: An Experimental Study of Group Opinion. Memorandum RM-5888-PR, Santa Monica, Calif., June 1969.
- . The Delphi Method, II: Structure of Experiments. Memorandum RM-5957-PR, Santa Monica, Calif., June 1969.
- . The Delphi Method, III: Use of Self-Ratings to Improve Group Estimates. Memorandum RM-6115-PR, Santa Monica, Calif., November 1969.
- . The Delphi Method, IV: Effect of Percentile Feedback and Feed-In of Relevant Facts. Memorandum RM-6118-PR, Santa Monica, Calif., March 1970.
- . An Elementary Cross-Impact Model. Report R-677-ARPA, Santa Monica, Calif., May 1971.
- . Experimental Assessment of Delphi Procedures with Group Value Judgments. Report R-612-ARPA, Santa Monica, Calif., February 1971.
- . A Delphi Examination of Civil Defense, Part I: Questions, Issues and Arguments. Memorandum RM-6247-1-ARPA, Santa Monica, Calif., May 1970.
- . A Delphi Examination of Civil Defense, Part II: Tabulation and Analysis of Results. Memorandum RM-6247-2-ARPA, Santa Monica, Calif., May 1970.
- . The Future as an Object of Research. Report P-3593, Santa Monica, Calif., April 1967.
- . Predicting the Future. Report P-3948, Santa Monica, Calif., October 1968.
- Research Analysis Corporation. A Forecast of Logistics Requirements. Report RAC-TP-427, McLean, Va., June 1971.

Unpublished Material

Budd, Lieutenant Colonel Roger Jr. "Technology Unemployment," Unpublished Air War College research report, Air University, Maxwell AFB, Alabama, 1972.