

WORLD WIDE WEB DELPHI REVIEW OF ENERGY R&D GOALS

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Abstract

Reviewing an organization's research and development (R&D) goals is crucial for its continued effectiveness. Traditional review techniques require reviewers to convene in a central place and may be dominated by highly vocal reviewers. This paper examines how a new technique, a Delphi review conducted over the World Wide Web, allows review of R&D goals with diminished influence from individual reviewers who may be geographically dispersed. How the technique might be implemented in a review of energy R&D goals is discussed.

Introduction

Periodic review of strategic goals is central to the survival and effectiveness of an organization. Indeed, organizational effectiveness has been defined as "the degree to which an organization realizes its goals."¹ Over time, interaction with the organization's environment and changes within the organization itself may precipitate changes in an organization's goals.² Organizations that do not review their goals regularly may find themselves in areas not directly related to their mission, expending resources in unproductive or outdated areas, missing opportunities for new growth, or working towards goals that are not achievable or unrealistic. Over time such organizations may experience a decreasing customer base, decreasing revenues, layoffs, and even bankruptcy. In the public sector this may manifest itself as decreasing support from traditional customers and stake holders, including members of the executive and legislative branches, decreasing funding and even elimination of the organization.

For public sector research and development (R&D) organizations, the long time periods between goal formation and realization reinforce the need for periodic review. It may take ten or twenty years to attain an R&D goal. During this time internal and external factors may affect realization of R&D goals. For instance, the market for a technology may shift, related R&D may make a technology obsolete or more pertinent, or constrained resources may make attainment of the goal unfeasible within the perceived window of opportunity.³

There are a variety of options available to review an organization's goals, including peer review, Delphi review, and computer-based techniques. Each review option has its

strengths and weaknesses. Some are more expensive than others, some are more time consuming, some limit interaction among participants. This paper examines how an application of the Delphi review process, developed by Sandia National Laboratories for use over the World Wide Web by the Department of Energy, addresses these shortcomings and how it might be tested in a review of energy R&D goals.

Options for Reviewing Goals

Peer Review

The traditional format for reviewing a government R&D organization is the peer review process. Peer review is "the judgement of scientific merit by other scientists working in, or close to the field in question."⁴ Most federal agencies relying strongly on peer review use it for prospective evaluation, while the U.S. Department of Energy (DOE) uses it more for post hoc evaluation or for evaluating projects already underway.⁵

The typical review process in the Department of Energy (DOE) uses five to nine qualified reviewers selected from academia, industry, government labs, and other sources. Reviewers receive a packet of documentation from a project's Principal Investigator, followed by an oral presentation by the program manager and principal investigator. Reviewers are allowed a brief period to discuss the projects and then complete a rating form. Following completion of the rating forms, project summary tally sheets are developed and shown to reviewers who then have the opportunity to examine, discuss, and revise their initial evaluations. A chairperson then selects a score for the project based on the reviewers ratings. A final evaluation of the project is completed after all projects have been reviewed.

It is only after evaluations are completed that reviewers discuss research needs for the future. Two issues are addressed: the potentially highest payoff research needs and opportunities, and the order of priority for these needs and opportunities. The amount of time spent discussing these prospective issues is small compared to the post hoc review.

The strength of the peer review process is that it allows direct interaction among reviewers, which may cause creative individuals to intellectually stimulate one another.

Reviewer interaction also contributes to some of peer review's weaknesses. The most vocal reviewers may exert undue influence in the process, or the process may suffer

from "group think", "bandwagon effects" and problems of reliability.^{6,7} In addition, peer reviews can be expensive, requiring the organization to pay for the experts' airfare, hotel accommodations, and perhaps time. The review must also be coordinated with the experts' busy schedules.

Delphi Review

A second option for reviewing goals is the Delphi technique. Originating at the Rand Corporation in the late 1940s to forecast futures, the Delphi technique is an iterative process for revealing areas of consensus and disagreement among experts. It has since become a well accepted method for supporting group-based decision-making in many fields. In a typical Delphi an expert group is assembled to interact through correspondence or face-to-face discussions in order to assess issues put forth by the organizer. Individuals may be experts in the same field or share a common interest, but care is taken to ensure that different points of view are represented. A moderator is used to keep the group dynamics focused on the issues. Steps in a typical Delphi process include:⁸

1. Administer the instrument, Round #1.
2. Collate, aggregate, and send the judgments from Round #1 back to the experts.
3. Administer the instrument, Round #2.
4. Repeat Step 2.
5. Administer the instrument, Round #3.
6. Repeat Step 2.
7. Prepare final report on results.

In the initial iteration of the Delphi, a problem statement and/or a delineation of issues and a questionnaire (the instrument) is given to a group of experts whose responses are statistically summarized and anonymously provided for a second iteration. In the second iteration, responses from the first iteration are considered by the experts as they complete the questionnaire a second time. The process continues with future iterations providing feedback from the previous round. The process ends when consensus is achieved (typically in no more than three iterations but there is no fixed limit) or when there is agreement to disagree.

The types of Delphi reviews that may be performed run along spatial and temporal dimensions. Delphis may be conducted where participants are in one location (face-to-face) or in remote locations. The advantage of the remote Delphi is that it allows larger groups to participate and it saves on travel costs for participating experts. The disadvantage is that it only allows anonymous comments, not anonymous discussions.⁹

Iterations of the survey instrument can be conducted in real time, immediately after the previous iteration is finished (synchronous Delphi), or they can take place over longer periods of time (asynchronous Delphi). The advantage of the asynchronous Delphi is that it allows respondents

the flexibility to decide when they will participate, but it also adds to the length of time for the review. The advantage of the synchronous Delphi is that it is quicker, but if this is the goal then the number of participants or the amount they contribute needs to be limited.

The advantage of the Delphi process is that it reduces undue influence from individual experts.¹⁰ Since there is less direct interaction among experts than in the peer review process, persons with dominant personalities have less chance of controlling the direction and outcome of the review process.

A disadvantage of the Delphi is that data are lost when participants are not allowed to interact directly¹¹. The intellectual stimulation contained in the peer review process may be reduced. This typically occurs in Delphis conducted through correspondence or when the technique is applied to large groups (30 to 100) where it is difficult to function well in a face-to-face environment.⁹ In smaller, face-to-face Delphis this is not a problem, except when dominant personalities or polarization among participants exists. This can and does occur and hence anonymity has become an essential design element in Delphis. Anonymity allows participants to present views that they might not give if their identity was known. The difficulty is allowing interaction and anonymity to occur simultaneously. Advances in computer technologies has begun to open this avenue of review.

Computer Based Techniques

A third review option is using computer-based techniques over a local area network (LAN) or a larger network such as the Internet or World Wide Web (the "Web"). The advantage in using the Web over a LAN is that it enables experts to conveniently participate wherever they are located. Surveys, reviews, and studies of various kinds have been successfully done this way, from using simple questionnaires delivered and collected electronically to the use of the Delphi process.⁹

Some of the many computer-based techniques which may be considered as candidate information gathering tools include:

- Survey/review materials delivered and collected by e-mail or at a Website
- Discussion forums
- Time-displaced threaded discussions/conferencing
- Real-time conferencing, and
- Time-displaced and real-time Delphi method implementations.

The first four of the above candidates are used widely in networks and on the Web in varying degrees of sophistication and for various purposes: to deliver and collect information, share views, exchange opinions, conduct debates, etc.

Using e-mail or a Website to deliver survey/review materials to a group of experts is a relatively simple process. Respondents download a questionnaire, fill in their answers, and then send the completed instrument back. Alternatively, they may answer on-line at the Website, perhaps downloading the questionnaire to ponder their answers off-line and then submit them on-line. However, there is no group interactive dynamics, though analysis of the results are usually published for the group and the intended audience to see. As such this process yields a simple statistical summary of individual responses.

Discussion forums in networks and the Web can be both live (chat) or occur over time (time-displaced), and moderated or unmoderated. Live, unmoderated forums wherein members of the general public join to discuss a particular subject are popular and the easiest to maintain. However, they are inefficient for collecting quality information and place the burden of finding nuggets of useful information on the processor of the collected "chat" text. The time-displaced version gives participants time to submit considered statements, but loses benefits arising from spontaneous interactions. Because the volume of data collected can be immense, there are specifically developed products to help process them (e.g., Listserv). Electronic conferencing has often been applied to the use of the various chat/conferencing tools to more serious "business" and implemented in networks/intranets and on the Internet/Web. Both time-displaced and real-time modes are organized more carefully. Security is better. It is an environment in which a selected group of experts may prefer to work.

Delphi reviews have been conducted using computers. Indeed, marrying the Delphi Method with computers increased its use, enhanced its efficiency of data capture and improved anonymity and voting techniques.^{9, 12} Computer-based Delphi processes are now widely used, including in group decision support systems. There are several custom software packages available that are designed to aid the implementation of computer-based Delphis (e.g., Group Systems for Windows, ConsensusUS). However, application to a wide-area-network, in which individuals from various geographic locations can participate, has not been pursued. All of the above computer based techniques have also been referred to as computer-mediated communications.¹³ Depending on the issues to be discussed and the information to be collected, each one of these might find use as objective and conditions require.

Web-based Delphi

A fourth review option, explored in this paper, attempts to combine the strengths of expert review, Delphi and computer based techniques into a modified Delphi technique conducted over the World Wide Web. The technique is similar to the traditional Delphi and computer-based Delphi in that expert opinion is obtained through iterations of a problem statement, definition of the issues,

presentation of questions and elicitation of anonymous responses. It is similar to the peer review committee in that it allows for direct, real time (albeit remote) interaction among experts by taking advantage of the conferencing software now readily available for Internet applications. The process that was developed is described in greater detail in the next section.

Although Delphis have been performed over local area networks, use of the Delphi Method on the Internet (or intranet) is only beginning. Moreover, there is a dearth of reports on completed Web-based Delphis. Perhaps this is because enabling tools are relatively new or that many activities have been conducted in confidence. At least one time-displaced (asynchronous) Delphi, where each iteration is performed at separate intervals instead of in real time, has been conducted. The study's director found the Web-based Delphi to be a valuable tool in rapidly bringing together views from 20 experts in the US and Canada without having to convene in a single location.¹⁴

The advantage to a Web-based Delphi process is the same as some computer-based Delphis - it allows the interaction contained in the expert review process while maintaining the anonymity of the experts contained in the traditional Delphi. Moreover, since the technique is conducted over the World Wide Web participants do not need to convene in a single location. This reduces the expense of flying experts in from around the country, and paying for their hotel accommodations and meals. It also reduces the demand upon the experts' time.

As with all computer-based Delphis, the disadvantage of the Web-based Delphi is that although interaction is allowed, face-to-face interaction is not. There may be something lost by not allowing such interaction. The Web-based Delphi also requires some computer expertise on the part of the experts. As transition to the World Wide Web continues, such requirements can be expected to decrease. The easy-to-use, graphically-rich current generation of Internet Web browsers is already beginning to reduce the computer expertise required of respondents. Likewise, server and development tools for Web-based applications are not only graphically rich, but also make the developers' task much easier, dramatically decreasing the cost of setting up Web-based Delphis.

Conducting a Web-based Delphi Review

Applying the Web-based Delphi process to a review of an organization's goals involves a number of steps. The review's objectives must be defined, a survey instrument developed, reviewers selected, an initial Web survey conducted, and subsequent iterations of the survey performed during a chat session. These steps are described below for a potential review of an energy R&D organization's goals.

Review Objectives

The first step in the process is to define the objectives of the review. The objective of an energy organization's review might be to gather opinions from experts in the appropriate energy fields on whether its mission was appropriate for a government agency, whether the mission could be achieved, and whether current performance measures would adequately capture progress towards the mission.

Survey Design

It is critical that a survey be designed that meets the objectives of the review. A survey for reviewing an energy organization's R&D goals might be divided into four thematic areas (used throughout the Delphi review):

- Organization's Mission
- Where We Are Now
- Where We Are Going
- How We Will Get There

The first section presents the mission of the organization. Comments are obtained on whether this is an appropriate mission for a government agency and what other areas might be included. A series of scenario's justifying the pursuit of the mission are also presented and comments requested. For example, scenarios might include trends for renewables, gas and other fuels; oil imports, baseline transportation use, and petroleum use reduction due to vehicle efficiency improvement. Finally, a series of outcome measures for the mission are presented with questions on whether those measures are appropriate.

The section "Where We Are Now" presents a series of indicators of the organization's current success, including R&D awards, consumer energy savings, alternatively fueled vehicles on the road, and weatherized homes among others. Reviewers are asked if the organization's success can be properly judged relative to its mission given those indicators.

The section "Where We Are Going" presents future estimates of benefits to the public and asks for adjustments to these trend lines based on the reviewer's experience and knowledge.

Finally, the section "How We Will Get There" presents budget figures across the organization's R&D portfolio and asks for adjustments to the level of funding for each area.

In addition to meeting the review's objectives the survey should address typical issues of survey design - validity, reliability and length. The layout of the questionnaire should take into account that the survey will be administered on a computer.

Selecting Reviewers

After defining the review objectives and designing the survey, potential reviewers may be identified. Reviewers may be selected using criteria such as:

- recent or long-term technical knowledge of R&D activities
- objective about possible bias, willing to identify any and all connections to the organization
- professionally balanced, covering universities, industry and the federal labs
- access to a computer with a modem and appropriate Web browser software
- willing to participate

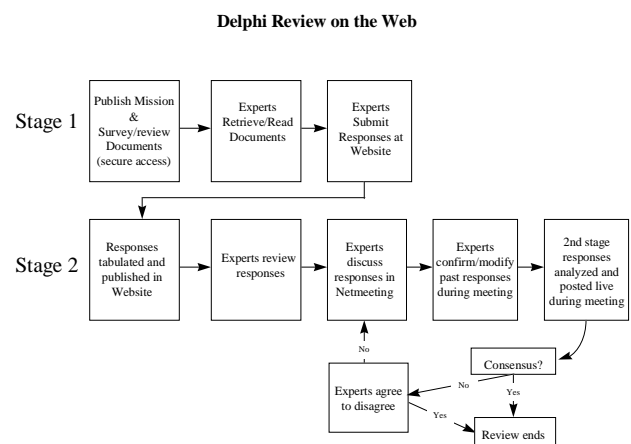
Design of the Web-based Delphi

The Web-based Delphi technique combines features of the remote, face-to-face, synchronous and asynchronous Delphis. The technique that was developed is presented in Figure 1.

Stage 1. The first stage contains features of a remote, asynchronous Delphi. Review materials and a survey instrument are published on the Web. Reviewers access the materials at their convenience through their Web browser and assigned password. Reviewers may respond to the questions on-line as they read the material or print the materials ahead of time and provide their answers in a subsequent log on.

Stage 2. The second stage contains features of a face-to-face, synchronous Delphi. It begins when a summary of reviewers' Stage 1 answers are published on the Web. Reviewers have a set period of time to examine the results of the first stage. After this period, the same reviewers are invited to a scheduled "net meeting" held at a designated Web site. Anonymity of respondents during discussions and for their answers and comments are ensured by providing aliases for log on.

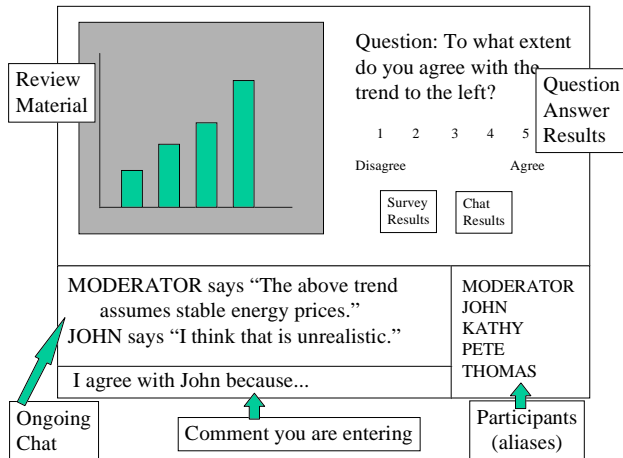
Figure 1



Once logged on to the Web site, reviewers are presented with a screen divided into the following two frames, as depicted in Figure 2:

- Review materials and questions for the issue under discussion
- A chat session for discussion of the issue

Figure 2
Stage 2 (Net Meeting) Screen



The net meeting proceeds along the same issues and questions as were covered in the stage 1 review, with perhaps some new issues included that arose from the stage 1 results. The session begins with a slide(s) on an issue and a related question on the top of the screen. Reviewers may view stage 1 responses to the question by selecting the “survey results” button. Participants proceed to discuss the slide(s), the question, and the stage 1 results using the chat box on the bottom of the screen. Aliases are used if so desired. A moderator directs the discussion and after a set amount of time asks reviewers to “vote” on the question at hand. A basic statistical analysis of responses is performed in real-time and reviewers may view this analysis by selecting the “chat results” button. The moderator then determines if discussion on the issue is to continue or if the group is to move on to the next question. If the discussion continues, another vote will be taken after the discussion is completed. After final votes are taken, the group moves on to the next question. The typical net meeting should run between two and three hours, depending on the amount of material to be reviewed.

Analyzing a Web-based Delphi Review

Analysis of the Web-based Delphi may be broken into two areas: analyzing responses relative to review objectives, and analyzing the Delphi process itself in terms of speed, cost, and ability of reviewers to fully participate.

Participant Responses

Data collected during stages one and two are used to answer questions related to specific review objectives. For instance, did reviewers agree that the mission of the organization is appropriate for a government agency? Such a question may be analyzed for convergence or divergence of responses over subsequent iterations of the instrument. Both results provide valuable information to the host organization. Convergence of responses suggests a consensus of reviewer opinion on a particular question - “yes, this is an appropriate role for government.” While divergence suggests a lack of consensus, the number and comments of those disagreeing with a question are indeed valuable information. An analysis of the chat discussion may reveal why divergence occurred by identifying views taken by participants - John thought that the agency's mission was appropriate but Kathy indicated that it was more appropriate for state government. Such data may not only tell the host organization *whether* it needs to revise its mission, but *how* it might do so.

The Web-based Delphi Process

Some fundamental questions must be asked of the Web-based Delphi itself. Did the process allow review objectives to be met in a timely, cost effective manner? Were any technological problems encountered? Did participants feel they could fully interact with others? To answer these questions the host organization may analyze its own records and ask participants to provide their impressions of the process in a post hoc survey.

The host organization, in this case the energy R&D organization conducting the review, can answer numerous questions by examining its own records. How long did the process take from defining the review's objectives to analyzing the results? Relative to the remote Delphi process conducted over time, it is likely that the Web-based Delphi process adds time and expense at certain stages and reduces time and expense at others. If the effort is started without conferencing facilities in the Website, then developing the Web survey and chat facility probably adds time and expense. Once this facility is in place, preparation of the instrument for the Web should not take longer than any other form of computer-based Delphi process. On the other hand, conducting the chat likely reduces time because each iteration is performed immediately after the previous one. The Web technology also allows data to be collected electronically, which decreases the time and money used for analysis. The overall review is probably quicker. In addition, stage 1 permits respondents to participate at their convenience within a prescribed time window, a process that could be refined in the future with threaded discussions and multiple iterations if both time and dynamics of the Delphi indicate this to be a preferred option.

Relative to the face-to-face Delphi conducted in real time, again the Web-based Delphi probably has additional costs and benefits. The startup Web-based Delphi probably

takes more time and money to develop. However, its implementation is much less expensive because reviewers do not have traveling expenses. With an operational facility, it should be more convenient to implement than the face-to-face Delphi.

A post hoc survey of participants can also provide insight into their views of the process. The survey might ask reviewers if they had any technological problems with the process. Were data connections slow? Did they get disconnected from the Website? Did all aspects of the chat tool work?

The survey can also provide impressions of the review process itself. What was the quality of reviewer interaction? Did they feel that interaction with other reviewers was restricted in any way? Was the displayed review material sufficient to inform their answers and discussions? Was sufficient material reviewed in the time allotted? Was the display of real time responses sufficient to inform further discussion?

Applications of the Web-based Delphi Review

Future applications of the Web-based Delphi will provide reference points for the above questions. Applications of the Web-based Delphi are being considered by the Department of Energy's Office of Energy Efficiency and Renewable Energy. Results of these applications will be disseminated as they become available.

As applications are developed, it should be kept in mind that the Web-based Delphi process described above is not intended to replace existing peer review, Delphi or computer-based techniques. The live form (stage 2) cannot provide the intensive interaction of the peer review process, although stage 1 with threaded discussions on issues could come close over an extended time period. It does not improve the well-established Delphis that already exist or technically enhance the application of computer-based techniques. Rather, the Web-based Delphi draws from all of these techniques to develop a niche of its own: conducting the process over a very wide network. It is intended to serve as a review tool for organizations finding themselves in one or more of the following situations:

- Reviewers are geographically dispersed and do not have time to fly to another location to conduct a review.
- Reviewers are geographically dispersed and the host organization does not have the resources for providing travel expenses.
- Live, anonymous interaction among reviewers is desired.
- Anonymous interaction among reviewers is desired over a longer period of time.

With these considerations in mind, the Office of Energy Efficiency and Renewable Energy is considering extending the application of the facility just developed beyond reviews of well-articulated policies or program implementations. It hopes to test the effectiveness of this tool for information-gathering on market transformation and technology diffusion issues - forward-looking activities where the Delphi process is particularly well-suited. It is examining the use of the process in a policy Delphi, where disagreement on issues is expected and positions of each side are examined more closely. Finally, it is considering opening up the process to more public forums.

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