Chapter

3

THE RESEARCH PROCESS – OVERVIEW

Introduction

Systematic, well-designed research provides an effective approach to the solution of many problems facing transportation agencies. Experience has shown that effective research programs follow a sequence of events, which include the activities shown in Figure 3. While Figure 3 shows the steps as discrete, the life of a research project should be considered as a continuum. In particular, implementation must be part of the research plan, and evaluation may be undertaken at the beginning or during the life of a project, as well as at its conclusion. The same activities are involved no matter whether the research is conducted by staff in-house, or through a research contract. In the latter case, there are additional steps involving selection and monitoring of the contractor. This chapter describes each of these activities. It also discusses client involvement in the research process, and some of the attributes of a successful researcher and research manager. Further information on contracts and contract administration, and on the organization and staffing of research departments is contained in NCHRP Synthesis 113 "Administration of Research, Development, and Implementation Activities in Highway Agencies" and in NCHRP Synthesis 231 "Managing Contract Research Programs".

Most transportation agencies have a manual that describes the administrative processes involved in managing the research program. A guide and a commentary have been published by the Transportation Research Board (8). The purpose of this chapter is not to deal with administrative issues, but to provide an overview of the major activities and issues involved in conducting in-house and contract research. Background information, additional detail, and examples are given in Appendix B.

Problem Statement Development

The development of a problem statement is the first formal step in identifying the need for research. In fact, in some agencies Problem Statements are called Needs Statements. A problem statement can be a simple document, but as a minimum should describe the problem, justify why research is needed, state what the research should accomplish, what the benefits will be, and, preferably, indicate the resources required, and the time available to complete the work.

Problem statements should be written by the client or user of the research results, who is in the strongest position to define what is needed and when. The client is also best equipped to determine what he is prepared to pay to find a solution to his problem. However, the input of researchers is often required to develop a high-quality problem statement. This is discussed further in the section 'Client Involvement in the Research Process'.

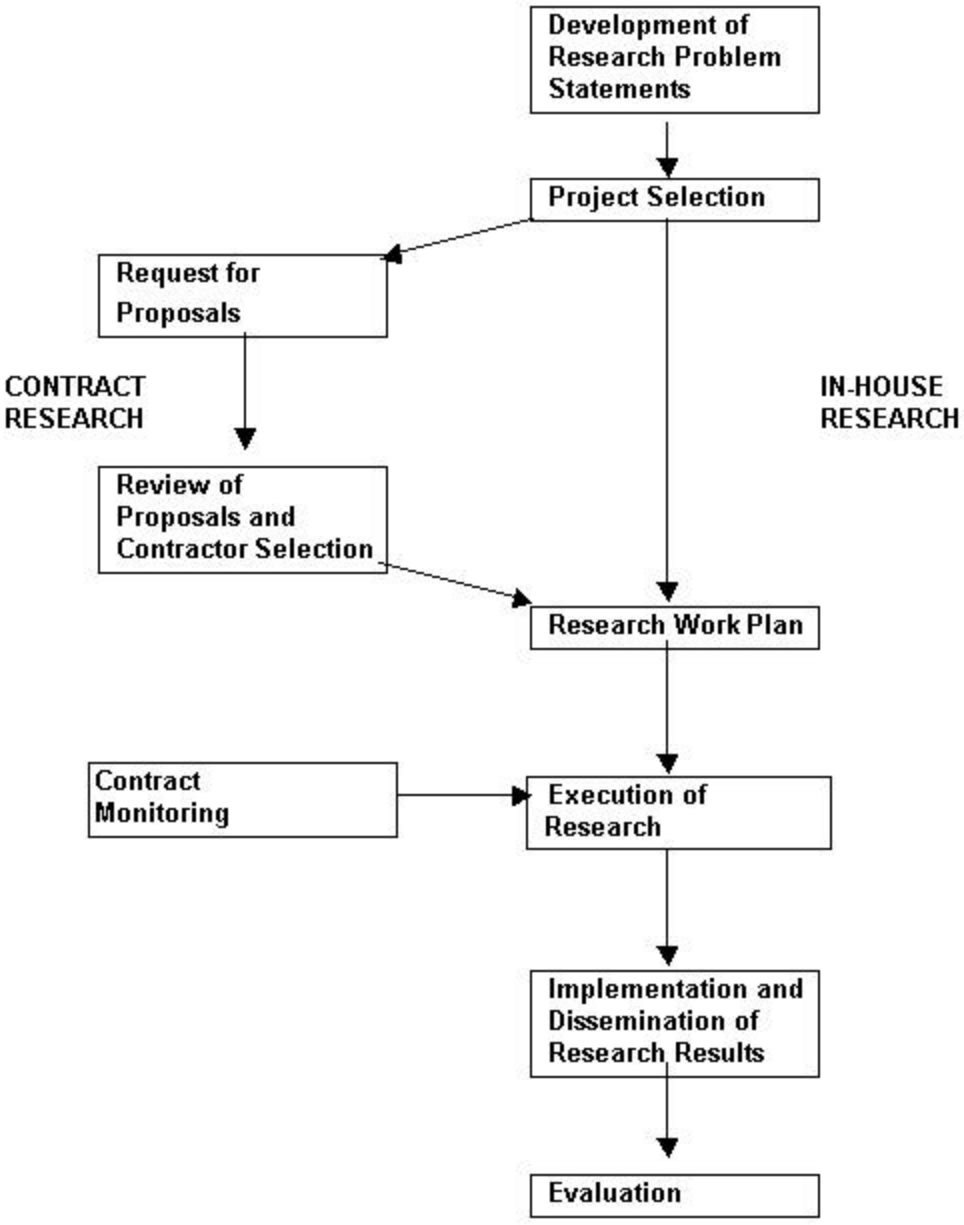

Figure 3 - Sequence of Events in a Successful Research Program

Project Selection

Most transportation agencies have a process in place for setting research priorities and selecting projects for the research work plan. While it is possible to identify general principles, the actual practices vary considerably with the organizational structure, and with the size and complexity of the research program.

Factors that affect the ranking of projects include:

- Is the problem within the scope of the program?
- Does the problem aim to satisfy an important need of the sponsor?
- Can the problem be solved by research?
- Is there a client group committed to supporting the project and implementing the results?
- Are satisfactory answers available, or are similar efforts underway elsewhere?
- Could other programs such as a pooled-fund study or a national research program solve the problem more efficiently?
- What is the probability of success in completing the project according to its scope, estimated cost, and time for completion?
- Are researchers and facilities available to do the work?
- Will the solution be timely?
- Does the project have a high benefit-cost ratio?
- Is there a clear implementation strategy?

The potential benefit-cost ratio may be a formal calculation, but is often a qualitative assessment by the researchers or a panel of experts. A qualitative assessment may be suspect, especially if made by experts who have a vested interest in seeing the research undertaken.

Many agencies make use of planning and program review committees to establish, or advise, the content of the research program, usually on an annual cycle. The members of the committee should represent the client groups of the research function and typically include representatives of design, construction, maintenance, planning, traffic, and district operations. Research staff may serve as non-voting resource persons. The planning and review committee may also include representatives from outside the agency such as from the FHWA or universities.

When the committee meets, projects in progress, as well as proposed projects, need to be considered in establishing the research program. Research projects tend to be self-perpetuating as new knowledge is gained and new directions identified. Extensions of existing projects should be subjected to the same scrutiny, and evaluated against the same criteria, as proposed new projects. For a committee to function effectively, members must have a clear understanding of the agency's research goals and must be prepared to put aside parochial interests and pet projects. Through meaningful discussion, the committee should attempt to reach a consensus on the content of the program, which is a much more satisfactory process than tabulating votes.

In many organizations there will be a group of projects, the "command performance", which must be included in the work plan because of political commitments, or the insistence of senior management.

Project selection is a complex process. There have been many attempts to develop models but none offer the advantages of an effective committee representing all the members of the research constituency. The product of the committee's efforts should be a research program that balances topics, risks, and anticipates future needs as well as addressing immediate problems.

Where the planning and review committee does not approve the research program, the authority usually rests with line management or an executive committee. Few jurisdictions have research executive committees, though such a committee can be very useful in providing a focus for research and setting policy. It is important that the committee not become involved in individual projects but define overall directions and objectives.

Requests for Qualifications or Proposals

In contract research programs, an investigator, or team of investigators must be hired to perform the research. This can be done by issuing either a Request for Qualifications (RFQ), or a Request for Proposals (RFP).

A Request for Qualifications is an invitation for individuals or organizations to express interest in undertaking a research contract. In fact, an alternative name for an RFQ is an Expression of Interest. An RFQ is normally used in one of two situations:

- When the work activities are known and the sponsor wishes to hire qualified people to complete the work.
- As the first step before issuing an RFP.

Some research programs use a two-step process to hire contractors, issuing an RFQ first, to be followed by an RFP sent only to those selected from the responses to the RFQ. Typically three to five proposals are solicited. The advantage of this approach is that the proposal review process is much less burdensome than when an open RFP is issued. In theory, the quality of the proposals is higher because proposers know the chances of success is higher than in an open competition. It is difficult to establish whether this is, in fact, the case, and proposal writers offer contrary opinions. The disadvantage of the two-step approach is that it tends to favor the established researcher and exclude from consideration relatively unknown researchers, who may have novel ideas.

There is considerable debate between clients, researchers, contracting officers and auditors as to whether an RFP should include a cost estimate, especially in contract research programs. Some will argue that if the needs are defined adequately, a research contract is like any other construction or services contract, and the cost should be determined by the bidder. However, as noted in Chapter One, there are varying degrees of quality and success in research. It is significant, that the majority of effective research programs include a limit on the cost of a project. By doing so, a number of requirements are satisfied. It is known whether the project can be included within the available budget and, the sponsor is giving an indication of the value of a solution. The preparation and evaluation of proposals are expensive undertakings, and the selection process difficult and time-consuming, even when a maximum cost is included. If the cost is not given, considerable effort may be wasted because proposers are not aware of the sponsor's expectations. Programs in which the anticipated cost is stated are much more likely to attract proposals from the best-qualified researchers, who prefer to compete on the basis of innovation and research approach, rather than price. Further, the practice of identifying the maximum cost of a project does not preclude the less expensive solution.

Research Proposals

Research proposals are usually prepared in response to an RFP, though some programs encourage unsolicited proposals. The proposal represents the opportunity for researchers to convince the sponsor to award them a contract. The sponsor is looking for evidence that the researchers have the time, abilities, facilities, and a plan that are likely to lead to the work being completed and implemented successfully. Most sponsors have specific requirements for the content and format of proposals. This simplifies the review process and provides the financial information needed for input to the agency's budget and expenditure control systems.

Review of Proposals and Contractor Selection

In the case of projects that include the budget, the selection of the contractor involves a technical evaluation of the competing proposals. The evaluation criteria should be developed before reviewing any of the proposals. The process, which will be used, should also be made known to those preparing the proposals.

Many transportation research programs use a standard set of criteria for all proposals, but apply weighting factors appropriate to the individual project. For example, a criterion such as the adequacy of facilities and equipment may be weighted heavily for a project that requires sophisticated laboratory techniques, but would be largely irrelevant in a desk study.

In programs in which the budget is established by the contractor, the evaluation of the competing proposals is much more difficult because there is a technical and financial component to the evaluation. The objective is to select the "best buy". There is no well-accepted method for making such a selection. One approach is to score each proposal, and divide the number of points by the cost to give a ratio of "points per dollar". The contract is then awarded to the proposal with the highest ratio, provided that the number of points exceeds a specified minimum, i.e. unacceptable proposals are not considered regardless of cost. Another approach is simply to use the judgement of experienced reviewers.

Research Work Plan

Every research study requires a work plan. This is for the benefit of the research team, the research manager, and the sponsor. The research plan should answer four questions:

1. What and how will the research be done?
2. What resources (people, equipment, facilities) will be required?
3. What will it cost?
4. When will it be done?

In the case of a contract research program, the research work plan normally consists of an amplification of the research proposal incorporating changes requested by the sponsor. In the case of in-house research, the preparation of the work plan represents the detailed planning phase of the study. It is an opportunity to develop a strategy for the research, assemble the research team, and anticipate what will be needed for successful implementation.

Specific requirements for the content of the work plan, and examples of the level of detail required, are given in Appendix C.

Execution of the Research

Detailed descriptions of the principal activities involved in undertaking research, including experimental design, data collection, and analysis and reporting, are given in Chapters Four to Six. The purpose of this section is to describe briefly considerations in monitoring contract research and in measuring the progress of in-house research.

As already noted in Chapter One, research work is inherently subject to a greater degree of uncertainty, unpredictability, risk of failure, or of digression, than other endeavors. While the

activities follow a prescribed plan, conducting research is not a mechanical process, and the plan must be modified continuously in response to the latest findings. Success depends largely on the talents and experience of the researcher. There is a tension between the objectives of the research, what is technically sound, physically possible, timely and affordable, and what is interesting and satisfying to the researcher.

In the case of in-house research, the key to maintaining progress and fiscal control is through regular reports to management, and preferably, also to a technical advisory committee. Technical progress should be measured against the work schedule, and milestones contained in the research plan; financial expenditures should be measured against the planned expenditures.

In the case of contract research, close communication between the contractor and the sponsor is essential. As with in-house research, the monitoring should have technical and financial components to ensure:

- high quality technical work is performed
- timely adherence to contract milestones
- the research remains focused on the objectives
- expenditures are in accordance with the research plan
- technical progress is commensurate with the expenditures.

Meetings between a technical advisory committee and the contractor can be very useful in contributing ideas and ensuring that the research is leading to a usable product. It also means there is staff from the client groups to act as champions for the project through both the execution and implementation phases. Meetings can be arranged at regular intervals, or to coincide with milestones in the project. Minutes should be kept of all meetings, paying particular attention to action items. In addition, the contractor should submit regular progress reports, often monthly, with more detailed reports every quarter.

Once problems develop in a research contract, be it for lack of direction, lack of effort, over-expenditures or changes in personnel, corrective action is very difficult unless taken as soon as problems arise. Otherwise, funds have been spent unproductively, and work cannot be completed as originally planned with the funds remaining. Actions such as deferring payments, or even changing contractors, can be taken, but the experience has been that once a project runs off course, the sponsor is faced with a salvage operation that is rarely successful.

Implementation and Dissemination of Research Results

Implementation involves putting research results into practice. Although Figure 3 shows implementation as the penultimate stage of the research process, implementation efforts begin much earlier. The strategy for implementation should be addressed in the research work plan, and throughout the conduct of the research. It is particularly important to identify early in the research process any barriers to implementation, such as policy documents, specifications, and standards that must be revised. The method of implementation should follow an implementation work plan, in the same way that the research activities follow the research work plan.

The members of the technical advisory committee can be very helpful in facilitating implementation efforts, and aiding the dissemination of research results. If the committee has been functioning effectively, client groups will be anticipating the results.

Some agencies, such as South Dakota, have a formal process for assessing research results and developing an implementation strategy. The project technical panel comments on the research

findings and approves or rejects the contractor's recommendations. The accepted recommendations are analyzed, and a set of implementation procedures developed. The procedures are circulated at the managerial level throughout the department and require the approval of the Secretary of the Department. The appropriate Division is assigned responsibility for each recommendation, and the Office of Research tracks the progress of the implementation efforts.

No matter how formal, it is essential that there be a process of assessing the results of the research, and preparing a strategy for implementation activities. Too hasty implementation is almost as bad as missed opportunities because it destroys the credibility of the researcher and the confidence of the client, such that future cooperation is jeopardized. The product must be packaged to suit the needs of the client, in the language of the client, and there must be technical support readily available at all times. Operational personnel cannot take undue risks on the in-service system because of the consequences of failure on safety, liability, publicity and political sensitivity. Users must have confidence in both the product and the researcher.

The National Highway Institute offers a workshop on the marketing of technology transfer (9). The objective of the workshop is to train highway personnel involved in technology transfer to be more effective in facilitating and expediting the technology transfer process. The intent is to improve the timeliness of implementation activities.

Recommended Practices

An NCHRP study (10) was undertaken to examine technology transfer methods and implementation practices. The objectives included identification of the factors most likely to encourage or impede the implementation of research results. The study found that no one formula will ensure successful implementation of research results, but key elements tend to occur frequently. The following recommendations, quoted directly from the report (10), describe practices found to promote successful implementation. These practices should occur in conjunction with one another whenever possible.

Plan for implementation. Conscious, planned efforts directed toward implementation create successful outcomes. Moreover, well-defined, flexible, and comprehensive goals, incorporating all players, are essential to implementation planning.

Fund implementation activities. A modest amount of funding to facilitate implementation activities is a high payback action. When appropriate funds are provided, barriers to implementation often can be overcome easily.

Commit qualified people to the job of implementation. Committing some of the technically qualified people as well as people who have sufficient authority to deal with potential administrative barriers will dramatically advance the implementation effort. Implementation is labor-intensive and should be considered primary work, not a collateral duty. Staff must be given time to perform the effort and credit for accomplishing the work.

Always address genuine need. Implementation of new products or processes works best when there is a need to change. Various conditions create these needs, and projects with less than genuine motivation rarely were cited as successful implementation experiences.

Select products or processes for implementation that have demonstrable advantages. The implementation effort is enhanced, if users can relate the benefits of implementing a new product or

process directly to their responsibilities. Products and processes that do what they are supposed to do and have advantages that can be seen by users were frequently reported as examples of successful cases.

Use pilot project, field demonstration, or field test results. Successful implementation activities usually involve adequately tested (sometimes demonstrated or piloted) and sufficiently developed products or processes. Collaboration with other agencies or states, use of national or regional centers for evaluation, observing "neighboring agencies" efforts, and partnerships with the private sector all can spread cost, reduce the time to implement innovations, and enhance confidence in the technical performance of the products or processes.

Elicit strong support from senior management. Senior management's endorsement and agency wide positive influence can eliminate potential barriers to the implementation of new products or processes. Every effort should be made to get support from the top technical and administrative managers overseeing the area of the agency in which the innovation is to implement.

Promote continuous collaboration between user and researcher/developer. Continuous collaboration will enhance the overall implementation. Researchers must be willing to spend time with users to understand their true needs. Users also must be willing to become more knowledgeable, when necessary, to implement research results more effectively. This type of collaboration generally does not occur without encouragement.

Choose researchers and vendors with practical experience. Researchers and technical experts must be able to bridge the gap between theory-driven research process and the users' practical needs. When this happens, the technical merits of the innovation are grasped more quickly, mid-course corrections in the research can occur if necessary, and final product is customized more effectively to the users' needs.

Do it - the final recommendation. The effectiveness of the key implementation strategies and practices has been demonstrated by state and local transportation professionals throughout the nation. They will work to varying degrees in diverse agencies and will assist in streamlining the implementation activities.

Evaluation of Research Projects

Evaluation is a neglected, but nevertheless important, activity in the life of a research project. An evaluation may be undertaken before a project begins, while it is in progress, or following its completion. There are a number of methods that can be useful in the evaluation process including expert opinion, user or client opinion, cost-benefit and cost effectiveness methods and analysis, case studies, and performance indicators.

Many projects can estimate costs, but benefits are not well suited for quantification in terms of cost, in which case, cost effectiveness should be considered. Those projects that are not suitable for cost benefit types of analyses are usually missing many advantages and disadvantages of the recommended application of the new technology, process, or practice, in which case cost effectiveness should be conducted.

Cost effectiveness is more useful and more often employed for implementation than cost benefit, primarily because it is easier for clients to understand, discuss, and trust

.

Cost benefit and cost effectiveness analysis activities should be included in research projects, whenever applicable, as opposed to waiting until after projects are completed. The justifications for this include: access to the same funding sources; to capture the momentum of the work and the experience and expertise of the investigators; to make recommendations more acceptable to clients and to readers of the Final Report.

Table 1 summarizes which of the evaluation methods are most useful at the beginning, during, and at the end of a research project (in addition to cost effectiveness analysis). The ideal evaluation model is recommended (11) to be:

- Select the projects based on user opinion, supplemented by expert opinion or information from performance indicators.
- Use a technical advisory committee to monitor the progress of the research with respect to cost, timeliness and achievement of technical objectives.
- Conduct a formal post-project evaluation to document the results, the use of the results, and the resulting impacts. If resources permit, cost-benefit methods should be used for projects with quantifiable benefits, and case studies where benefits cannot be quantified. If not, user surveys should be used.

Table 1: Applicability of Evaluation Methods to Transportation R&D (11)

Method	When Deciding What R&D to Conduct	During the R&D Process	After the R&D is Complete
Expert opinion	A good supplement to user/client opinion (to provide them with information) and performance indicators (to value the indicators). Not particularly useful on its own.	Good way to monitor the technical progress of the R&D	Good way of obtaining high quality information regarding the quality and potential usefulness and impacts of the R&D, with relatively little effort.
User/client opinion	The best method for deciding what R&D to conduct, especially when supplemented by expert opinion or information from performance indicators.	Limited usefulness.	A fairly easy way of finding out if the R&D has been/is likely to be useful; but the results are more useful for program management purposes than reporting purposes.
Cost-benefit methods	Can be a useful way of prioritizing potential projects. Also, forces decision makers to think about the critical success factors. However, fairly time-consuming	Can be useful for monitoring if a cost-benefit analysis has been done at the beginning	The best way of documenting the impacts of R&D whose benefits can be identified and quantified. Assumptions need to be clearly documented and, in general, the most challenging method to use correctly.
Case studies	Not useful	Not useful.	The best way of documenting the impacts of R&D whose benefits can be identified but not quantified. Not particularly challenging.
Performance indicators	A good supplement to user/client opinion.	Can be useful in structuring the monitoring process.	Limited usefulness.

Investigation has shown that evaluation is most frequently conducted at the beginning of the research process. There is little evaluation of research in progress, and even less after the research has been completed. Nevertheless, it is becoming increasingly important to demonstrate the value of individual research projects, and of research programs. While the tools are imperfect, especially where it is difficult to state the benefits quantitatively, they are sufficient to provide very useful information.

Miscellaneous Tools and Considerations

Program and Product Evaluation - A Conceptual Framework

Each year central agencies in the federal or state government invest in research and development to improve the movement of goods and people and the safety of the motoring public. As new programs and products emerge from this research and development, questions need to be answered about how well they are performing. Figure 4 gives a conceptual framework for such evaluations.

The first distinction made in Figure 4 separates evaluations into formative and summative evaluations. Formative evaluations are analyses conducted on programs and products still under development. Such evaluations serve to provide feedback to the researchers/developers, and to facilitate enhancements to the program or product when there is still considerable flexibility. Summative evaluations, in contrast, are conducted on programs and products that are ready for installation in DOT operations.

Summative evaluations can be further subdivided into process evaluations and effectiveness evaluations. Process evaluations focus first, on initial installation of programs and products, i.e. construction and/or deployment, and second, on how well they are operated or used. Effectiveness evaluations, on the other hand, address whether, and to what extent, a program or product is meeting stated objectives.

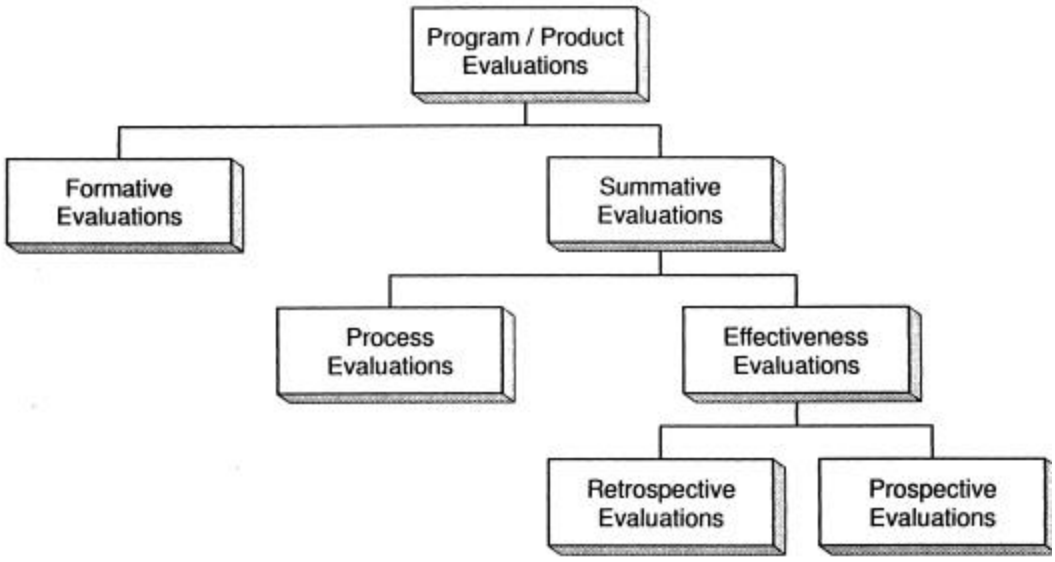

Figure 4: Conceptual Framework for Program and Product Evaluations (18)

Overview of Survey and Questionnaire Design

Some research projects require the development, administration, and analysis of surveys or questionnaires. Questionnaires require the researcher to consider specific research design elements, which is the subject of this section.

Surveys have considerable appeal, because they are seen as reflecting the attitudes, preferences and opinions of the marketplace in the case of surveys run by business, and of the public, in the case of those run by governments. Lay people tend to have some doubt, about why relatively few respondents can be seen as representing the whole population.

Survey research solicits self-reported verbal information from people about themselves. Plausible generalization derives from applying a set of systematic and orderly procedures known as sample survey research. These procedures specify what information is to be obtained, how it is to be collected and from whom it will be solicited.

The three kinds of information obtained from surveys are description, behavior and preference. Descriptions usually include data such as respondents' income, age, education, and family composition. Patterns of the respondent's behavior such as choice of transportation mode and time of travel are often of interest. Preference is often the major question in opinion polls regarding issues of social and political import.

There are four methods of implementation:

1) Mail-out surveys have the advantages of low cost for the researcher, convenience and anonymity for the respondent and reduced interviewer bias. The disadvantages include lower response rate than other methods, longer turn around time and self-selection.
2) In-person or face-to-face interviews have the advantages of flexibility, high response rate and assurance that instructions are followed. The disadvantages include higher cost, interviewer bias, less anonymity, and occasionally some threat to personal safety.
3) Telephone surveys have the advantages of rapid data collection, lower cost than face-to-face surveys, and anonymity. The disadvantages include less control, less credibility, and lack of visual materials.
4) Internet-based surveys, which are becoming more popular, are a way to solicit responses from individuals or households. The advantages are low cost. The disadvantages are of course associated with the sampling frame of households or individuals with internet access and computer literacy, and the method of initial contact of households or individuals. The internet is most commonly being used as a supplement to telephone surveys.

Stages of the Survey Research Process

The following stages and procedures are necessary for orderly conduct of the research:

Stage 1: Identification of the Purpose of the Research and the Method. The researcher must develop explicit statements of the information needed. It must also be clear that survey research is more appropriate than a literature search, direct measurement or observation. Also, a choice among mail-out, in-person and telephone implementation must be made.
Stage 2: Research Schedule and Budget. The timing, resource requirements and dollar costs must be planned and reviewed from time to time during the life of the project.
Stage 3: The Sampling Frame. The researchers should be relatively certain that the selected population possesses the information, and that a fair sample is obtainable.
Stage 4: Design of the Questionnaire. The researcher has to devise a series of unbiased, well-structured questions that will obtain the information identified in Stage 1. Thought must be given to possible multiple interpretations of each word or phrase. Longer questionnaires tend to lead to lower response rates, so every item included must be necessary to uncover the information sought.
Stage 5: Pre-test of the Questionnaire. It is necessary to pretest the questionnaire under survey conditions. Poorly worded questions that escaped the researcher's attention can be recast.

Stage 6: Selection and Training of Interviewers. If interviewers have facility with the questionnaire, they are better able to obtain accurate information and generate and sustain interest of the respondents.
Stage 7: Coding, Analysis and Reporting Results. The information should be recorded, summarized, placed in tabular form suitable for application of such statistical techniques as hypothesis testing and correlation/regression analysis.

Delphi Technique

A forecast is an estimate based on informed opinion, of what is likely to happen in some area of interest within a particular time period. Various tools or techniques are available to help forecasters in predicting future occurrences: growth or diffusion curves, trend extrapolation, or use of analogous experiences and contexts from the past. The Delphi technique is another important method.

The Delphi technique is an alternative to round-table discussion as a method of generating a group consensus. The criticism leveled at the round-table discussion is that very often the results are forced, because of undue influence of those with the greatest supposed authority, or of unwillingness of some participants to back off publicly stated opinions, or the bandwagon effect of the majority opinion, or that of some dominant coalition.

The origin of the technique was Project Delphi, a Rand Corporation study conducted for the U.S. Air Force in the 1950's, to gather opinions on critical defense problems. Since then, the method has been applied widely in both the private and public sectors.

A Delphi study is usually conducted by a mailed questionnaire, but computer conferencing is a recent alternative. In a forecasting application, the panel is given a list of events that might occur in the future, and a time scale on which to locate the occurrence of the event. They might also be asked to record opinions on the desirability of the event. The opinions are usually obtained by several rounds in which the experts are asked for their opinions more than once. In between rounds, the distribution of responses (typically divided into quartiles) is fed back to the panelists. Respondents with answers outside the middle quartiles are asked to give explanations, and these explanations are summarized anonymously for the next round.

These procedures tend to produce convergence, or alternatively, the realization that different respondents are starting with different databases or very different interpretations of the same database.

One of the attractions of the Delphi technique is that results can be achieved with small panels, and on topics for which data are very sparse. The group is not a random sample, and so considerations of conventional statistics relating to sample size do not apply.

Client Involvement in the Research Process

A research program designed and pursued in relative isolation from its potential clients is unlikely to be successful in developing practical solutions to relevant problems. Client involvement is essential throughout the research process from problem statement development, through execution, to implementation of the results. Involving the client promotes a better understanding of the problem by the researchers, aids in the generation of practical research ideas, and adds assurance that prompt and effective implementation will take place.

The skills of the researchers and clients are complementary and the two groups should function as a team. As noted in the section on problem statement development, the client will often require the assistance of the researcher to develop the client's ideas into a detailed problem statement. This spirit of cooperation needs to extend throughout the life of the project.

Technical advisory committees or project panels are often used to provide technical guidance and advice during the execution and implementation phases of a project. The membership of technical advisory committees is usually composed of technical experts from the client groups. The role of the committee is to make available a wide range of knowledge to solving the problem, to exchange ideas, provide advice, stimulate interest in the research in the client's office, and make preparations for implementation of the results. The committee must be careful to strike a balance between encouraging and monitoring the progress of the research without attempting to manage the project and deny the researcher the freedom necessary for a creative solution.

In agencies that have a program planning and review committee, this group has a formal role in the management of the research program. The review function requires periodic (often semi-annual) evaluation of each project to ensure that the work is progressing according to the schedule and budget, and that the research will be successful.

Care and Nurturing of the Researchers

Most professions like to view their members as being different from the mainstream, and deserving of special treatment. While this is also true of researchers, an argument can be advanced that researchers respond to management and reward systems that differ from many other professional employees.

Research work is inevitably subject to a greater degree of uncertainty than other endeavors, and largely depends on the initiative, talents and experience of the practitioner to reach a fruitful conclusion. It must be remembered that there is an almost infinite range of success, from barely satisfying the objectives, to defining a truly elegant solution. The quality of the staff and the working environment are critical factors in attaining the higher levels of success.

In addition to providing the necessary long-term commitment, facilities and resources, research management has a crucial role to play in generating good morale by adopting a facilitating rather than a dictatorial management style. Executive management must view research as an investment, and a key ingredient in moving the agency forward. Good researchers are rare, and do not tend to be mobile, so that nurturing the personal and professional growth of the researcher is a sound investment. The role of management is difficult, because the fine line between focusing on a project's objectives, and providing freedom for spontaneous or speculative enquiries, is elusive.

Technical researchers tend to be segregated from the remainder of the organization, and, to be effective, must be insulated from daily operational problems. Outsiders must also be tolerant of the research culture, which often takes the form of an uncommunicative, tight community in which business is conducted in its own specialized language. However, research cannot be conducted in a vacuum. As noted in the previous section, client groups must be involved throughout the research process, and researchers and clients must make extraordinary efforts to communicate effectively. Clients must be tolerant of the researcher's need for freedom, while the researcher must be sensitive to the client's need for a timely, practical solution communicated in language the client understands.

The research group must also be very sensitive to the needs of executive management. The researchers must find a way to establish two-way communication in the language of senior management, without compromising their scientific integrity, or providing a level of detail that is not required. It is essential that research becomes a key element in corporate decision-making because the alternative is not to survive the next corporate restructuring.

Good researchers are highly motivated, and salary is only part of the reward system. Personal freedom, management support, and recognition by peers are equally important. Researchers must be encouraged to participate in the broader scientific community, both to ensure that their work is state-of-the-art, and to provide opportunities for peer recognition. This includes supporting visits to other institutions, the publication of work in scientific journals and attending conferences within the field of the researcher's speciality. The dissemination of results is vitally important in earning reciprocity from others in the field. Individuals and institutions unable or unwilling to contribute ideas or information are identified quickly and shunned by the scientific community.

Research is also closely linked with education. These links arise from the need for continuing professional development and from the benefits of cross-fertilization between applied researchers and university faculties and students. Some of these contacts take the form of contractual assignments, cooperative ventures or simply exchanges of information. Others arise from working as loaned staff, sabbaticals, or the recruitment of new personnel. A climate of fostering these exchanges and contacts, through formal and informal arrangements, benefits the research of both parties. The benefits are both tangible, such as contributions of information, ideas, shared facilities, caliber of recruits, and intangible, such as peer recognition and building morale.