NCHRP

NATIONAL
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RESEARCH
PROGRAM

REPORT 442

Systems Approach to Evaluating Innovations for Integration into Highway Practice

TRANSPORTATION RESEARCH BOARD

NATIONAL RESEARCH COUNCIL

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Systems Approach to Evaluating Innovations for Integration into Highway Practice

WORCESTER POLYTECHNIC INSTITUTE
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
Worcester, MA

SUBJECT AREAS
Planning and Administration

Research Sponsored by the American Association of State Highway and Transportation Officials
in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD — NATIONAL RESEARCH COUNCIL

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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FOREWORD

By Staff
Transportation Research Board

This report presents a comprehensive approach to evaluating innovations to determine whether they should be integrated into current procedure. The approach considers both quantitative (e.g., costs, environmental impacts) and qualitative (e.g., training methods, acceptability to interest groups) information. The report also demonstrates the approach by considering innovations ranging from ground-penetrating radar, to light-emitting diode traffic signals, to partnering. Use of this approach should facilitate the evaluation of innovations and should result in higher-quality decisions. The report will be useful to anyone who is considering adopting an innovation.

Research, both public and private, is usually intended to produce new, beneficial innovations. Ultimately, the success of an innovation will depend on how widely it is used. Adopting an innovation requires a thorough, systematic analysis of the resulting risks and opportunities and an understanding of how the innovation affects the entire organization, the other parts of the transportation infrastructure, and the environment. A benefit of systematic analysis is that it can identify modifications that improve an innovation's effectiveness. Such analysis can require significant effort, particularly if there is not enough information readily available to assess the various effects.

Many engineering disciplines use systems analysis to consider all aspects of a proposed change, to clarify all assumptions, and to identify and manage the associated implementation requirements and challenges. Unfortunately, this is rarely done in highway engineering, perhaps because of the misguided perception that highway engineering is not as complex as other engineering disciplines; yet, in the highway industry, the service environment is rarely well defined, no easy methods exist to predict long-term performance of materials and systems, and the cost of failure is extremely high.

Under NCHRP Project 20-46, "Systems Approach to Evaluating Innovations for Integration into Highway Practice," Worcester Polytechnic Institute (WPI) identified proven innovation-evaluation methods used in the private and public sectors and evaluated these methods to determine their suitability to the highway environment. WPI then identified and defined the parameters and criteria that highway decision makers find critical in choosing whether to use innovations. This information was used to develop a systems analysis approach to evaluate innovations for implementation in the highway environment.

This report presents a systematic and comprehensive approach to evaluating innovations for integration into current practice. Use of the report should increase decision makers' confidence in their decision to implement an innovation. Researchers, developers, and innovators will also find it useful as they seek implementation of the results of their efforts.

CONTENTS

AUTHOR ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 20-46 by the Department of Civil and Environmental Engineering at Worcester Polytechnic Institute (WPI).

Dr. Roberto Pietroforte, Associate Professor, WPI, was the principal investigator. Dr. Tahar El-Korchi, Professor, WPI, was coinvestigator. The project also benefited from the research assistance of Rahul Dharankar, graduate student, WPI.

SYSTEMS APPROACH TO EVALUATING INNOVATIONS FOR INTEGRATION INTO HIGHWAY PRACTICE

SUMMARY Every year, considerable effort is spent evaluating innovations that can be used in the planning, design, construction, maintenance, and operation of highway facilities. The use of a common and systematic evaluation approach by transportation agencies would improve the effectiveness of the evaluation process and the productivity of human resources. The main objective of NCHRP Project 20-46, "Systems Approach to Evaluating Innovations for Integration into Highway Practice," was to develop guidelines for the systematic evaluation of innovations by state DOT officials.

The guidelines are designed to help state DOT officials in

- Researching and organizing information and data about a considered innovation;
- Screening alternative innovations and making a selection for evaluation;
- Developing an evaluation plan;
- Analyzing the main characteristics of an innovation, including its fit with state DOT resources and the feasibility of implementation;
- Assessing the effects of an innovation within and outside a state DOT;
- Addressing possible procedural or organizational concerns and developing strategies for eliminating or mitigating these concerns; and
- Defining requirements and planning for implementation.

The Guidelines

The guidelines consist of four main parts: (1) a step-by-step illustration of the evaluation approach, (2) a description of the methods (tools) to be used during evaluation activities, (3) applications of the approach to different innovations, and (4) an annotated bibliography. An appendix documents the current evaluation practices of selected state DOTs.

The first part of the guidelines presents a nine-step evaluation process—a logical roadmap for a state DOT's assessment of an innovation. A more detailed overview of these steps can be seen on the webpage of the project (cee.wpi.edu/nchrp20-46). Each evaluation step is supported by suggested issues to be addressed by evaluators, clarifications or recommendations about the major activities of the step, and possible tools

for processing information for completing the step. Possible barriers to an innovation's implementation are also addressed.

The second part of the guidelines describes 10 evaluation tools. Many of these tools can be used in more than one step of the evaluation process.

The third part of the guidelines consists of eight brief case studies that illustrate the use of the evaluation process in the areas of engineering design, traffic management and control, and construction contracting. The examples outline the most relevant issues considered in evaluating these innovations.

The fourth part of the guidelines contains an annotated bibliography that addresses specific information needs of state DOT officials during evaluation and implementation planning activities.

Effects of the Guidelines

The progressive incorporation of the guidelines into state DOT operations is expected to have the following positive short- and long-term effects:

- Increased efficiency of evaluation activities within state DOTs,
- Higher probability of successful innovation implementation, and
- Improved communication and sharing of evaluation data among agencies and between the private and public sectors.

PART I

EVALUATION APPROACH

INTRODUCTION

Presently, a significant time lag exists between the possibility or availability of innovations and their widespread adoption and use in highway practice. Several institutional, operational, and cultural barriers have created this gap. The purpose of this project was to develop a set of guidelines that will assist transportation officials in evaluating innovations and the feasibility of their implementation. The guidelines present a systematic approach to evaluation that will reduce the amount of both effort and time spent on innovation evaluation by transportation officials on a daily basis.

The topic of evaluating innovations deserves some clarification. In this project, an innovation is defined as a concept, material, product, process, or policy that can be used in the planning, design, construction, maintenance, or operation of a highway facility. This broad definition of innovation also includes the transfer of technology or know-how that may occur between private enterprises and public agencies. In this project, evaluation is defined as a process that deals with information in the form of facts and values. In addition to facts (i.e., the technical characteristics of an innovation), several other issues must be considered in analyzing an innovation—expected benefits, effects, constraints, and possible risks. The gathering of all pertinent information does not conclude the evaluation process, because a decision requires an expression of value to be associated with this information. Value can be assigned according to objective and subjective parameters. In the first case, quantitative modeling (e.g., the measurement of performance indicators) prevails; in the second case, the experience and intuition of the evaluator applies. In other words, quantitative methods alone cannot be used for a successful evaluation—they must be complemented by subjective judgement.

In the guidelines, the evaluation process is modeled as a series of steps that provide information about a considered innovation. In these steps, issues related to the nature of an innovation, its short- and long-term effects, and the feasibility of implementation within the constraints of an agency's resources are addressed. The process culminates in an attribution of value to the information and data that are gathered in these steps. Value or merit reflects the priorities and constraints of the agency. The evaluation process is characterized by analytical and synthesizing activities that use specific methods to gather and to organize information about the considered innovation or to define logical relationships between implementation and its effects.

The organization of the guidelines, consequently, reflects the above-described matters of evaluation. A step-by-step description of the evaluation approach (Part I) is complemented by an explanation of the information processing and valuation methods to be used during the process (Part II). Examples illustrate the application of the approach to a set of recently adopted innovations (Part III). An annotated bibliography that focuses on evaluation and related methods completes the guidelines (Part IV).

OVERVIEW OF THE EVALUATION APPROACH

The approach to the evaluation of innovation consists of the following nine logical steps:

1. Screen the innovation.
2. Consider the evaluation implications of the innovation.
3. Identify the characteristics of the innovation.
4. Identify the effects of the innovation.
5. Assess the fit of the innovation.
6. Assess the feasibility of the innovation.
7. Verify raised issues and develop evaluation criteria.
8. Apply evaluation methods and verify results.
9. Plan for implementation.

Figure 1 summarizes the full evaluation process whose steps, in practice, are not undertaken in the sequential order shown above. Step 8, for example, may be undertaken at any point of the process, provided that the proper evaluation method is used. Other activities, such as Steps 3, 4, 5, and 6, are performed simultaneously. In practice, the overall evaluation process is subject to iterations. Each step is implemented by using a set of information processing supports, such as predefined questions and checklists of considerations. The process has three main break-in points according to which the evaluation activities may be interrupted, more precisely at the end of the screening (Step 1), raising issues (Steps 3, 4, 5, and 6), and evaluating (Step 8) steps. Step 9, planning for implementation, may or may not take place, depending on the results of the evaluation process. The purpose of the break-in points is to save time and resources during the process, particularly when interim findings are not satisfactory. Following is a brief illustration of the steps.

- Step 1, *Screen the innovation*, is initiated by answering a small set of questions whose focus is to assess the relevance of the proposed innovation to the mission and needs of a transportation agency. The five-activity step is completed with the decision about whether the considered innovation deserves to be investigated further.
- Step 2, *Consider the evaluation implications of the innovation*, addresses the resource requirements for evaluating the innovation, establishes the related committee, and develops an evaluation plan.
- Steps 3 and 4, *Identify the characteristics and effects of the innovation*, and 5 and 6, *Assess the fit and feasibility of the innovation*, raise and define issues about the technological characteristics, effects, and compatibility of the innovation with an agency's resources and the feasibility of implementation. After the completion of these steps, the process is characterized by a second decision about the prosecution of the evaluation process.
- Step 7, *Verify raised issues and develop evaluation criteria*, organizes the issues into areas of concern and verifies comprehensiveness through a checklist. After the completion of this task, the defined issues are transformed into sets of evaluation criteria to be measured. A second checklist of relevant criteria supports this step.
- Step 8, *Apply evaluation methods and verify results*, judges the listed factors according to three types of assessments: qualitative measurements (positive or negative answers), ordinal scaling (answers in relative terms, e.g., from high to low), and quantitative measurements (numerical indicators from scoring models and economic analysis). After the verification of the findings, the last decision-making point focuses on the possible implementation of the considered innovation or other courses of action.

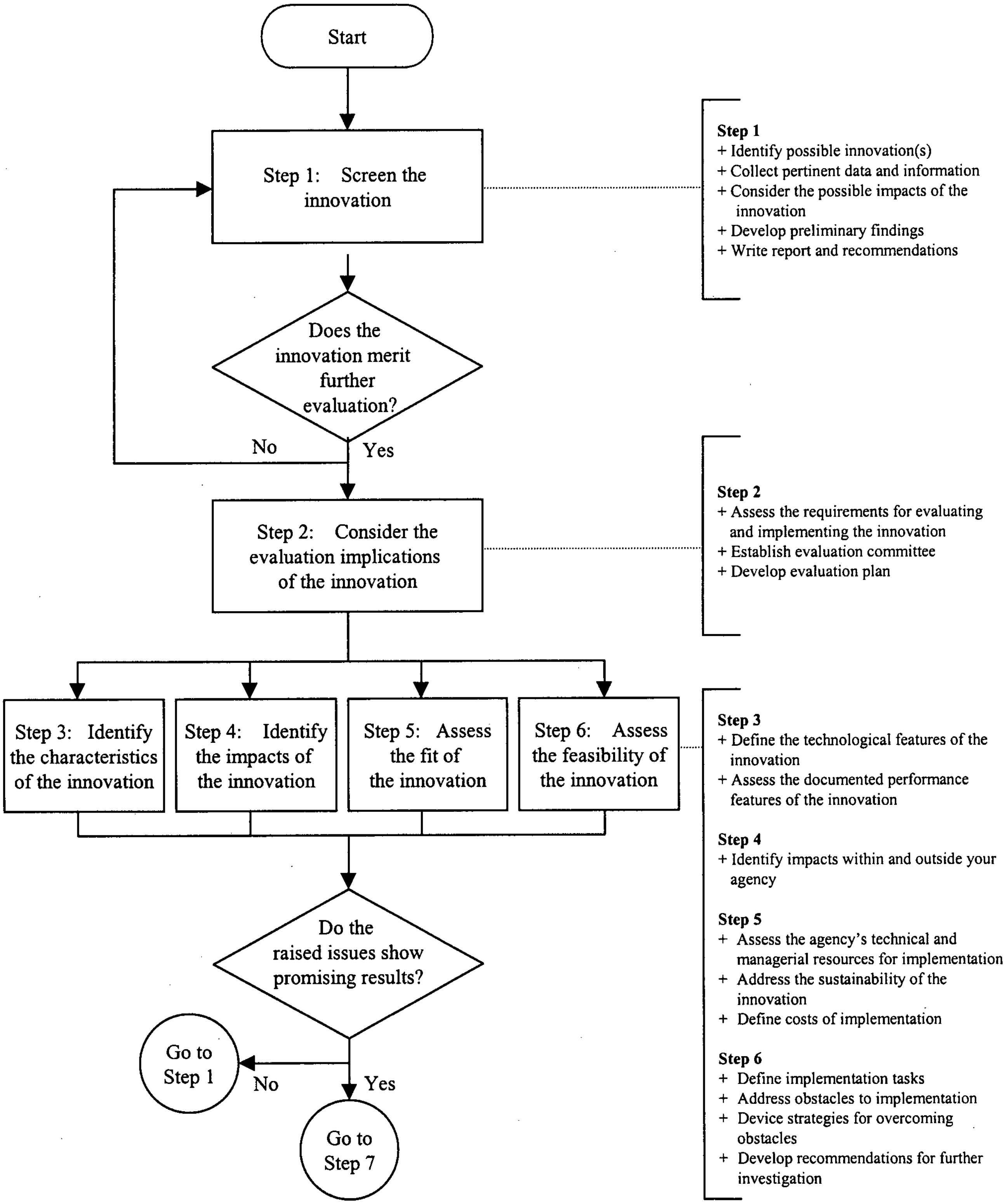

Figure 1. Evaluation process overview.

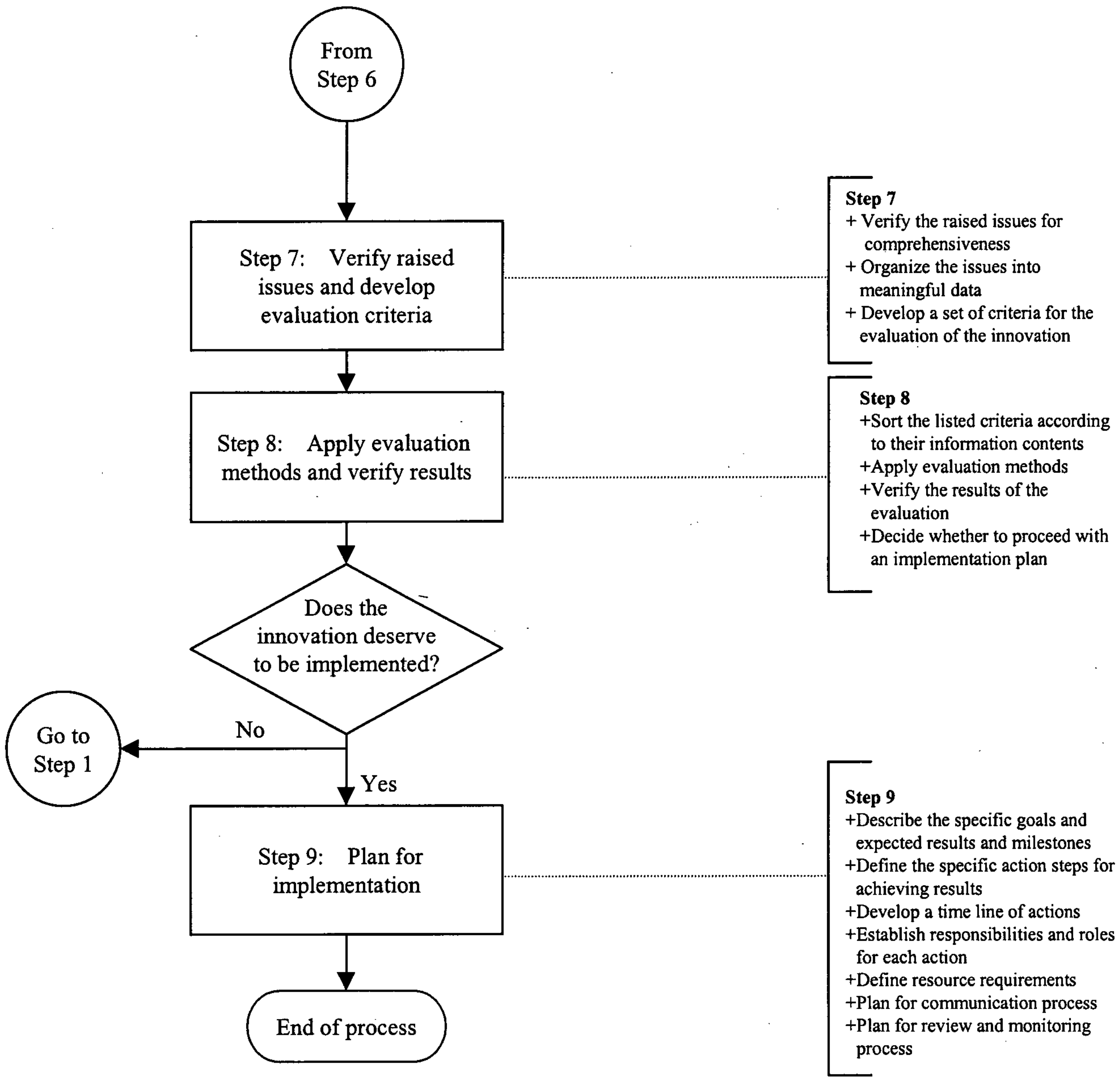

Figure 1. (Continued).

- Step 9, *Plan for implementation*, develops the implementation plan of the considered innovation. A checklist of relevant factors supports this step.

STEP-BY-STEP INSTRUCTIONS FOR THE EVALUATION PROCESS

This part of the guidelines contains detailed instructions for undertaking the nine steps of the evaluation process. The instructions for each step, whose format follows that of the *Continuous Process Improvement Guide* (*1*), are organized according to the following criteria:

(a) The objectives of the evaluation step (OBJECTIVE);
(b) The main activities of the step and, where possible, the inputs to these activities (KEY ACTIVITIES and INPUTS);
(c) A set of predefined issues to be raised and addressed that refer to a particular aspect of the innovation and its implementation (QUESTIONS/ ISSUES);
(d) A set of clarifications and recommendations for the implementation of the step (TIPS);
(e) Suggestions about the methods to be used for processing information and, where necessary, evaluating data (TOOLS); and
(f) References that may be consulted during the undertaking of the step (REFERENCES).

In Steps 1, 7, and 9, evaluators are advised to use the provided checklists, which facilitate the organization of information and data. The completion of the first six steps entails the consideration of approximately 70 issues that relate to four areas of concern: attributes of the innovation, impacts of the innovation, resources of the agency, and feasibility of implementation. This large number of issues reflects the general approach of the guidelines (i.e., their application to the widest possible range of innovations). This to say that the evaluation of some innovations does not require the consideration of all suggested issues. Evaluators are advised to examine all the issues before starting evaluation and to discard those that are not applicable to a given innovation. A further reduction of informative efforts can be achieved by assigning a weight (or a merit) to each suggested issue according to its relevance to the agency's needs and constraints. Weighting facilitates the identification of where the informative efforts should be concentrated. Considerable effort was spent in classifying each issue according to distinct areas of concerns. Evaluators should be aware that the same issue could be relevant to more than one area of concern and that redundancies may occur.

Several important milestones characterize the evaluation process:

- In Step 1, an initial report that recommends whether the considered innovation deserves further investigation is developed.
- In Step 2, an evaluation committee is established. A multiple composition is a prerequisite for comprehensive and objective analysis, because different points of view reduce the possibility of omissions and biases in evaluation. When necessary, the inclusion of stakeholders reduces possible implementation barriers.
- In Step 7, a report that addresses evaluation criteria is developed. The criteria build upon the organization of data that are gathered in the previous steps. These data should reflect the intents of accuracy and comprehensiveness rather than those of false precision and should be structured to lead to a reliable measurement in Step 8.

STEP 1: SCREEN THE INNOVATION

OBJECTIVES:

- To assess the relevance of an innovation to the mission and needs of your transportation agency.
- To develop recommendations for further evaluation, or other action, of the considered innovation.

KEY ACTIVITIES:	INPUTS:
• Identify possible innovation(s).	• Research proposals, vendor requests, federal/ state programs.
• Collect pertinent data and information.	• Performance evaluation results; pertinent standards and specifications; related legislation or mandates. See Checklist A.
• Consider the possible effects of the innovation.	• See Questions/Issues.
• Develop preliminary findings and verify/ expand their contents.	• See Checklist B.
• Write report and recommendations.	• Agency's protocols.

QUESTIONS/ISSUES:

The following questions address the main issues that will be further analyzed during the evaluation process. They relate to four categories of concerns: the fit of the considered innovation with your agency's mission and needs, and the advantages, feasibility, and desirability of the innovation.

- Is the gathered documentation of innovation adequate to this initial evaluation?

Mission
- Which agency need does the innovation satisfy? Does it support the mission of your agency?

Advantages
- What opportunities for improved performance of existing conditions are offered by the innovation? Can these opportunities be defined clearly?
- What are the limitations of the innovation as identified from the documentation? Are they acceptable?

Feasibility
- How can the innovation be integrated into current operations or practice, or both?

Desirability
- Is the innovation cost-effective?
- How does the innovation compare with other alternatives in satisfying your agency's needs?
- Can the innovation be used for multiple applications?

Once all these issues have been addressed, use Checklist B for summarizing your considerations. Having reached preliminary conclusions about the pros and cons of the innovation, address the following:

- Does the innovation deserve further investigation?
- Is the allocation of additional time and resources worthwhile?

TIPS:

- This task identifies the main opportunities offered by a considered innovation. These opportunities should be clearly defined and easily communicated in the task report, so that other parties can authorize the following evaluation process. Unsolved issues that need further analysis or clarification should be noted.
- The output of this task consists of a series of initial assessments that need further refinement. Cost or performance predictions, for example, can be fully verified only when additional information or data are available (e.g., the results of a pilot project). In the initial stages of an evaluation process, it is more efficient to make robust predictions than to attempt accurate measurements when information is scarce.
- The task report should contain the summary of the findings with reference to
  - Innovation identification
  - Innovation contact information
  - Innovation description (e.g., benefits and limitations)
  - Evaluation information
  - Suggestions for action

TOOLS:

- Checklists
- Estimating techniques (for cost predictions)
- Expert opinion
- Ranking and scoring models (for evaluating alternatives)

REFERENCES:

- Schoenbern, T. F., and J. M. Fredette. "So You Want To Set Up a Technology Evaluation Program?" *Technology Evaluation Workbook*, Federal Laboratory Consortium and U.S. Regional Technology Transfer Centers, 1997.
- Cooper, R. G. "An Empirically Derived New Product Project Selection Model." *IEEE Transactions on Engineering Management*, Vol. EM-28, No. 3 (August 1981), pp. 2–11.

Checklist A: Information Sources and Access

Transportation professionals have access to numerous primary information sources, such as technical reports, books, and journals. Secondary sources, such as library catalogs, holdings lists, and bibliographic databases, could be used to access this information, although they often convey or imply ownership. The following lists some of the principal sources of information.

Primary sources

- Technical reports
  - Internal and external reports
  - Highway Innovative Technology Evaluation Center (HITEC) reports
  - American Society for Testing and Materials (ASTM) reports
  - National Transportation Product Evaluation Program (NTPEP) reports
  - NCHRP publications
  - TRB publications
- Books
- Journals
  - Journals and periodicals (e.g., Better Roads, Roads & Bridges, etc.)
  - Journals and publications of trade associations [e.g., National Asphalt Pavement Association (NAPA), American Concrete Pavement Association (ACPA), etc.]
  - Journals of professional associations [e.g., Institute of Transportation Engineers (ITE), National Association of County Engineers (NACE), etc.]
  - TRB Transportation Research Records
  - AASHTO standards
  - Environmental Protection Agency (EPA) publications
- Conference proceedings
- Laws and regulations
- Directories, almanacs, encyclopedias
- Newspapers, newsletters from various state DOTs
- Data sets
- Laboratory notebooks
- Best practices
- Expertise
- Research-in-progress description
- Policies and procedures

Secondary sources

- Library catalogs
- Holdings lists
- Union lists
- Bibliographic databases
  - First Search (ArticleFirst and Books-In-Print Online)
  - National Transportation Information Services (NTIS) Database

  - Transportation Research Information Services (TRIS) Database
  - International Road Research Database (IRRD)
  - TRANSPORT [includes IRRD and European Conference of Ministers for Transport (ECMT) TRANSDOC databases]
  - COMPENDEX
- Contacts
  - Suppliers and industry representatives
  - Peers from other units within the DOT
  - Peers from other state DOTs
  - Officials from other public agencies
  - University professors
  - Engineering firms
  - Technology evaluation centers
  - Technology transfer centers
- World Wide Web
  - TRB home page
  - Home pages of more than 30 state DOTs
  - AASHTO
  - U.S. DOT [FHWA, Strategic Highway Research Program (SHRP), Bureau of Transportation Statistics (BTS), National Highway Transportation Safety Administration (NHTSA), U.S. House Committee on Transportation and Infrastructure]
  - ITE
  - American Traffic Safety Services Association (ATSSA)
  - More than 15 foreign transportation departments
  - U.S. Department of Energy–Office of Transportation Technologies
  - Many U.S. universities
  - UnCover Periodical Article Database
  - Compendex Web
  - Engineering Information (EI) Village
  - ProQuest Direct–ABI Inform (formerly known as American Business Information)
  - Search engines (AlltheWeb, Yahoo, Lycos, Excite, Alta-Vista, and so forth)
- Clearinghouses
- Help lines
  - BTS's statistical information line
- Syntheses

Table 1 summarizes the most frequently used secondary sources of transportation information and their most critical gaps:

TABLE 1 Secondary sources of information and their gaps

Source	Summary	Gaps
Clearinghouses and Help Lines	Clearinghouses provide subject-specific information, e.g., those at Northwestern University's Infrastructure Technology Institute and North Carolina State University's Center for Transportation and the Environment. Help lines, such as BTS's Statistical Information Line, provide information on a wide range of topics and research.	• Comprehensiveness: can only provide access to information of which they are aware. • Web-based clearinghouses are emerging. They are limited in that their scope, coverage, and linkages are incomplete.
Colleagues	Personal contacts are among the most common means of obtaining transportation-related information.	• Information is not comprehensive and may be biased. • Mid-level managers and technical staff have fewer opportunities to interact with colleagues than do top managers. • No comprehensive directory of expertise is available.
Databases	Provide access to citations by searching bibliographic records. TRIS (Transportation Research Information Services) and IRRD (International Road Research Database) are the most well-know transportation examples. Others used in transportation are COMPENDEX, ABI-INFORM, Trade & Industry Index, and Predicasts. TRIS also provides access to research in progress, syntheses, and best practices (see below).	• Timeliness: are large time gaps between publication of materials and their inclusion in a database. • Many materials never reach databases. • Can be cumbersome to search. • For TRIS, mandate to send in research-in-progress summaries is not enforced: erodes confidence in the information's quality and comprehensiveness. • TRIS reporting needs to be simplified. • Require specialized training to use effectively.
Library Catalogs	Record, describe, and index the resources of a collection. Usually classify information and assign subject headings.	• Lack of coordination and links between library catalogs means duplication of holdings and inefficiency in searching. • Do not include unpublished materials.
Syntheses	Concise reports written for an identified audience. The National Cooperative Highway Research Program (NCHRP), for example, synthesizes the knowledge available on a subject through reports on various practices.	• NCHRP funds only 12 projects a year. • Is an 18-24 month turnaround time for publication and no feedback mechanism.
Union Lists of Holdings	A complete record of holdings for a given group of libraries or for a certain type of materials. In any format, these lists assist with identifying a lending source for an information request. The Transportation Division of the Special Libraries Association publishes a union list of transportation serials.	• Lack comprehensiveness. • Escalating subscription costs adversely impact information service budgets.
WWW-Built Indexes and Search Engines	Serving millions of users a day, search engines construct indexes and find information on the WWW. They send out "messengers" to every site they can identify and then download and examine these pages to extract indexing information.	• Indexing lacks standardization. • Information is rarely classified, i.e., a report vs. a bibliographic entry or an advertisement. • Search engines recognize text only; cannot index password-protected information. • Requires specialized training

SOURCE: Minutes of TRB Committee on Conduct of Research (A5001) August 1998.

Checklist B: Screen the Innovation

Effects			Comments	Wt.
Reduced cost and time	A	NA		
Increased performance (e.g., safety, efficiency, energy consumption, pollution reduction, aesthetics)	A	NA		

Fit

Agency's mission	A	NA		
Customer's needs or problems	A	NA		

Feasibility

Integrability into agency's existing procedures and practice	A	NA		
Environmental concerns have been considered	A	NA		
Regulatory and legislative concerns have been considered	A	NA		

Desirability

Superior performance in relation to other innovation alternatives	A	NA		
Implementation potential	A	NA		
Cost/required performance	A	NA		
Scope of application/use	A	NA		

A = Applicable
NA = Not applicable
Wt. = Weight or merit

STEP 2: ADDRESS THE EVALUATION IMPLICATIONS OF THE INNOVATION

OBJECTIVES:

- To define the main evaluation and implementation implications of the innovation.
- To develop an evaluation plan that reflects the characteristics of the considered innovation and the resources that are required for its evaluation.

KEY ACTIVITIES:	INPUTS:
• Assess the characteristics of the innovation that affect evaluation and implementation.	• Reports of previous implementations, agency's know-how.
• Establish evaluation committee.	• Agency personnel, consultants and stakeholders.
• Develop evaluation plan.	• Agency's protocols. See Tools for the Evaluation Process.

QUESTIONS/ISSUES:

Issues regarding the evaluation of the innovation include the following:

- Does your agency have the know-how for handling the innovation? What type of expertise is needed for its evaluation? Where can this expertise be found?
- Does the innovation cross functional/unit boundaries within the agency? Identify all the personnel or units that are affected by the innovation.
- Who is the customer or the recipient of the innovation?
- Who is the owner of the implementation process of the innovation?
- Who else (outside your agency) may have an interest in or be affected by the innovation?
- Consider whether there are different values or interests among the parties that are affected directly or indirectly by the innovation. How would you solve these potential conflicts?

The composition of the evaluation committee should reflect consideration of the above-listed issues and should have a sufficient cross section of subject matter aspects. After the establishment of the committee, the following issues are relevant to the development of the evaluation plan:

- What are the technical objectives?
- How should the evaluation process be organized?
- What tasks are needed for the complete evaluation of the innovation (e.g., tests, pilot projects, and workshops)?
- Who will be involved in these tasks?

- What are the main milestones, and what is the timetable?
- How much will the completion of evaluation cost?
- How will funding be procured?
- What and where are the relevant sources of information for sustaining the evaluation process?

TIPS:

- The features of an innovation influence the composition of the evaluation committee. For example, an innovation's implementation may affect a single or multiple agency units or may involve outside stakeholders such as contractors, suppliers, or local communities. Consequently, the composition of the evaluation committee must reflect both the full spectrum of the parties affected by the innovation and the expertise that is required for the evaluation activities.
- When multiple groups are involved in the evaluation process, increased communication is necessary for developing a common understanding and for building the team.
- The evaluation of an innovation sometimes requires a specific evaluation policy, such as the exclusion of some interested parties. For example, the adoption of an innovation may benefit your agency, but reduce the work volume or market of a contractor or supplier, who therefore will not be sympathetic with the initiative. Other cases may induce particular bargaining positions in your agency: an innovation may be advocated by outside stakeholders who may not want to share the benefits with your agency.
- The implementation of an innovation may entail reorganization within your agency. This requirement is often encountered when the innovation is a new process or a new way of "doing things," such as in partnering or a total quality management (TQM) program that involves groups with different perspectives. In this regard, the evaluation plan should also contain the groundwork for overcoming possible resistance to change (a subject further considered in Step 6).

TOOLS:

- Action plans
- Cause-and-effect diagrams
- Expert opinion
- Group discussion and consensus
- Influence diagrams
- Time-scheduling techniques

REFERENCES:

- Bryson, J. M., and A. L. Delbecq. "A Contingent Approach to Strategy and Tactics in Project Planning." *Journal of American Planning Association*, April 1979, pp. 167–178.
- Innovative Technology Evaluation Center. "Technical Protocol." Civil Engineering Research Foundation, no date.

STEP 3: IDENTIFY THE CHARACTERISTICS OF THE INNOVATION

OBJECTIVE:

- To raise and address the technological and performance issues of the considered innovation.

KEY ACTIVITIES:

- Define the innovation's technological features and the criteria for addressing them.
- Assess the documented performance features and the reliability of data.

QUESTIONS/ISSUES:

Technological issues

- What are the main features of the innovation? Hard features may be a new material, component, or hardware; soft features may be a new process, system, or design.
- Do these features represent an incremental or a radical change from the existing practice or procedures of your agency?
- In this last regard, what needs to be changed to implement the innovation?
- Is the innovation adoptable in a phased fashion?
- Is it clear how all possible technical concerns will be addressed? If so, what steps are necessary for their full consideration? Who will take care of them?
- Does the implementation of the innovation expose your agency to liability (e.g., environmental hazards, safety issues)?
- Is the innovation characterized by proprietary technology? If so, how will your agency cope with such a constraint?
- Is the innovation capable of evolving with changes in system performance requirements and technology?

Performance issues

- Does the documentation clarify the performance aspects of the innovation?
- How reliable are the available data about the performance of innovation?
- Do the data refer to conditions and use that are the same as those envisioned by the agency?
- If not, what modifications should be made?
- To what extent could these modifications affect the expected performance?
- What types of additional data (e.g., test results, studies) are necessary for demonstrating the performance of the innovation? Are these data available?

TIPS:

- Step 3 is concerned with the consideration of the attributes of the innovation that can facilitate or hinder its implementation. For example, a new product or process may not have been tested adequately or proven. Available performance data may refer to use or conditions that differ from those envisioned by your agency.
- In this step and in Steps 4–6, the evaluation committee raises and gathers all the necessary issues that should be taken into account for the possible implementation of the innovation. The steps address four areas of concerns: the characteristics of the innovation (Step 3), its effects (Step 4), its compatibility with your agency's resources (Step 5), and the feasibility of implementation (Step 6). Because many issues are interrelated and may be classified according to more than one area of concern, the considerations of each area will result from an iterative process.
- The analytical process should build upon the preliminary considerations developed in Step 1, *Screen the Innovation.* The evaluation committee may want initially to treat each area of concern independently. The four lists resulting from consideration of each area of concern are then compared and expanded by finding logical relationships among the raised issues and finalized by eliminating duplications.

TOOLS:

- Cause-and-effect diagrams
- Checklists
- Expert opinion
- Influence diagrams
- Peer discussion and consensus

REFERENCES:

- Bikson, T. K., S. A. Law, M. Markovich, and B. T. Harder. "Appendix A: A National Survey of Implementation Practices in Surface Transportation." In *NCHRP Report 382: Facilitating the Implementation of Research Findings*, Transportation Research Board, National Research Council, Washington, D.C., 1996.
- Innovative Technology Evaluation Center. "Technical Protocol." Civil Engineering Research Foundation, no date.

STEP 4: IDENTIFY THE EFFECTS OF THE INNOVATION

OBJECTIVE:

- To raise and address the possible effects of the considered innovation.

KEY ACTIVITIES:

- Identify the possible effects on your agency during and after the implementation of the innovation with reference to
  - Overall net benefits,
  - Required changes and actions for implementation, and
  - Risks or limitations in realizing the benefits.
- Identify the possible effects outside your agency during and after implementation with reference to local communities, road users, industry, and the environment.

QUESTIONS/ISSUES:

Effects within your agency

- What are the overall benefits of implementing the innovation?
- Are these benefits sustainable over time?
- What are the possible risks or limitations in realizing the benefits?
- What are the changes (e.g., work procedures, standards, and specifications) or actions (e.g., training) that are required for implementing the innovation?
- Having identified the required changes, what are the overall costs for implementing and sustaining the continuous use of the innovation?
- In conclusion, is the innovation a cost-effective undertaking?

Effects outside your agency

- What is the effect of the innovation on road users and local communities during and after implementation?
- What is the effect on the local construction and supply industry?
- Is there any possible negative environmental impact from the innovation?
- Does the adoption of the innovation enhance the public image of your agency?
- If there are concerns (e.g., past failures), how can they be minimized or eliminated?

TIPS:

- Some of the measurable benefits for your agency are savings that relate to life-cycle cost, material, labor and construction costs, project duration, litigation costs, personnel time, equipment and installations costs, consulting services costs, reduced energy consumption, and reduced number of injuries. Other types of benefits are reduced air and water pollution, reduced congestion, increased safety, better ridership, improved aesthetics, greater convenience, reduced effect of noise and vibration on contiguous properties and occupants, and recyclability.

- In assessing the costs borne by your agency, estimate all the necessary resources that are needed for implementing, using, and monitoring the innovation over time. Consider items such as personnel work-hours, testing, pilot projects, training, evaluation activities, outside consultants, and information dissemination. Indirect costs include items such as effects on road users and local communities and environment-related factors (e.g., pollution and depletion of natural resources). Direct and indirect costs are also addressed in Step 5.
- In practice, the effects (addressed in this step) and performance features of the innovation (addressed in Step 3) cannot be fully defined initially. The consideration of these issues, however, prepares the ground for setting the objectives of a testing program, pilot project, or the like—actions that ultimately provide a comprehensive picture of the innovation.
- In organizing data about benefits, costs, and possible effects, consider the use of the following type of classification table (Table 2):

TABLE 2 Classification of an innovation's benefits, costs, and effects

			Organizations			
Type of benefit/ cost/effect	**Users (type)**	**General population**	State DOT	Other public agency	Private sector	**Environment (type)**
1.						
2.						
3.						

TOOLS:

- Cause-and-effect diagrams
- Checklists
- Estimating techniques
- Expert opinion
- Influence diagrams
- Peer discussion and consensus
- Time-scheduling techniques

REFERENCES:

- Cooper, R. G. "An Empirically Derived New Product Selection Model." *IEEE Transactions on Engineering Management*, Vol. EM-28, No. 3 (August 1981), pp. 54–61.
- Merrifield, D. B. *Evaluating R&D and New Product Development Ventures: An Overview of Assessment Methods*. Center for the Utilization of Federal Technology, National Transportation Information Services, U.S. Department of Commerce, 1986.
- Innovative Technology Evaluation Center. "Technical Protocol." Civil Engineering Research Foundation, no date.

STEP 5: ASSESS THE FIT OF THE INNOVATION

OBJECTIVE:

- To raise and address the issue of compatibility of the considered innovation with the resources of your agency.

KEY ACTIVITIES:

- Assess whether your agency has the technical and managerial resources for implementing the innovation.
- Assess and address the sustainability of the innovation after implementation.
- Define the direct and indirect costs of implementation.

QUESTIONS/ISSUES:

Consider whether your agency has the ability to implement the considered innovation by addressing the following:

- Availability of in-house know-how and technical capabilities for implementation;
- Availability of appropriate personnel in charge of implementation;
- Possible need for personnel training and for services by outside consultants, or both;
- Need for management commitment and support;
- Availability of reliable providers (if required); and
- Need for any other possible resource for implementation.

Having considered the above-listed issues, answer the following:

- Who will bear the costs of implementation?
- If implementation results in indirect costs, who will pay for them?
- How can these funds be raised?

If implemented, the success of the innovation depends on its sustainability and improvement over the years. Address the following issues:

- Resources for continuous monitoring and the measurement of results,
- Costs related to the possible need for information dissemination,
- Possible management turnover, and
- Continuous availability of outside providers.

TIPS:

- The implementation of the innovation and its continuous use may entail permanent changes within your agency that require adaptability and learning attitudes among the personnel involved. These capabilities and technical expertise should be the main criteria for selecting the personnel who will implement and use the innovation.
- Confirm that all the conditions for continuous use of the innovation (e.g., management turnover, availability of reliable suppliers, etc.) can be reasonably preserved in the future.
- Remember that user needs and requirements are not static. Adopted technologies and processes should be adaptable to changes.
- The success of an innovation is also measured by the extent of its diffusion.

TOOLS:

- Cause-and-effect diagrams
- Checklists
- Estimating techniques
- Expert opinion
- Influence diagrams
- Peer discussion and consensus
- SWOT analysis

REFERENCES:

- Bryson, J. M. *Strategic Planning for Public and Nonprofit Organizations*. Revised edition. Jossey-Bass Publishers, San Francisco, 1995.
- Bryson, J. M., and A. L. Delbecq. "A Contingent Approach to Strategy and Tactics in Project Planning." *Journal of American Planning Association,* April 1979, pp. 167–178.
- Bikson, T. K., S. A. Law, M. Markovich, and B. T. Harder. *NCHRP Report 382: Facilitating the Implementation of Research Findings*. Transportation Research Board, National Research Council, Washington D.C., 1996.

STEP 6: ASSESS THE FEASIBILITY OF THE INNOVATION

OBJECTIVES:

- To assess the feasibility of implementing the considered innovation.
- To decide whether the innovation deserves further investigation.

KEY ACTIVITIES:

- Define the tasks that lead to a successful implementation of the innovation.
- Address any possible resistance to the introduction of the innovation.
- Devise strategies for overcoming possible resistance.
- Develop recommendations for additional analysis and evaluation.

QUESTIONS/ISSUES:

Assess the feasibility of the considered innovation by addressing the following:

- What are the reasons for and benefits of introducing the innovation? Define the reasons.
- Identify all the parties that could benefit directly or indirectly from the innovation. Are they supportive? If not, how would you convince them that these benefits could be achieved?
- What type of procedural challenges does the implementation present?
- Is there a need for coordination with other parties (e.g., public agencies) or other in-house activities and programs? What actions are necessary for ensuring proper coordination?
- What tasks are needed to ensure successful implementation?
- Who controls the critical elements of the implementation process (from Step 2)?
- How would you involve these controllers and avoid their possible noncooperation, procrastination, or "tokenism"? Outline a strategy to deal with possible resistance to change, including human factors.
- Which individual or interest group (e.g., contractors, suppliers, the public, abutting communities) outside your agency may offer resistance to implementation? Outline a strategy for overcoming such possible resistance. What are the pros and cons of this strategy?
- Is the innovation acceptable to or supported by regulatory or funding agencies or does it conform to your state legislation? If not, what type of changes or actions are necessary for it to become acceptable?
- Have all possible environmental, procedural, and legal concerns been addressed?

This task concludes the four-step investigation of the innovation. Having achieved a better understanding of the innovation's pros and cons, address the following:

- Does the innovation offer enough advantages to warrant additional evaluation?

TIPS:

- The introduction of a given innovation leads to changes within and outside your agency. Those affected or expected to be involved may resist change. According to Bryson (*2*), changes can be readily implemented if they
  - Are conceptually and operationally clear.
  - Fit with the values of all key implementers.
  - Are based on a well-understood theory or cause-effect relationship.
  - Can be demonstrated and made "real" to the bulk of the implementers before to the implementation. (In other words, people should have a chance to see what they are supposed to do before they have to do it.)
- Depending on the situation and the type of innovation, you may want to consider the payoffs and rewards necessary to gain the wholehearted acceptance of stakeholders. Have clear incentives favoring implementation by relevant departments, interest groups, and individuals.
- Within your agency, barriers to innovation may include turf battles, resistance to change, inability to think "outside the box," and lack of commitment from process controllers and top management.

TOOLS:

- Cause-and-effect diagrams
- Checklists
- Expert opinion
- Influence diagrams
- Peer discussion and consensus
- SWOT analysis

REFERENCES:

- Bryson, J. M. *Strategic Planning for Public and Nonprofit Organizations.* Revised edition. Jossey-Bass Publishers, San Francisco, 1995.
- Bryson, J. M., and F. K. Alston. *Creating and Implementing Your Strategic Plan.* Jossey-Bass Publishers, San Francisco, 1996.
- Bikson, T. K., S. A. Law, M. Markovich, and B. T. Harder. *NCHRP Report 382: Facilitating the Implementation of Research Findings.* Transportation Research Board, National Research Council, Washington D.C., 1996.

STEP 7: VERIFY RAISED ISSUES AND DEVELOP EVALUATION CRITERIA

OBJECTIVES:

- To systematize the previously raised considerations about the innovation.
- To finalize the necessary information for evaluation.

KEY ACTIVITIES:	INPUTS:
• Verify/expand the considerations of Steps 3, 4, 5, and 6 for comprehensiveness.	• Results of Steps 3, 4, 5, and 6. See Checklist C.
• Organize/synthesize the raised issues into a set of meaningful data.	• See Checklist C.
• From these data, develop a set of criteria for the evaluation of the innovation and its implementation.	• See Checklist D.

QUESTIONS/ISSUES:

- Step 7 builds upon the informing process of Steps 3, 4, 5, and 6, and upon the decision that the considered innovation offers enough advantages to warrant further resources and time for evaluation.
- The gathering of all the necessary information for an informed decision about the considered innovation is completed in this task. Data such as effects, risks, opinions, economic issues, and reports are verified or updated for comprehensiveness, so that they include all the factors that are critical for the effectiveness of the evaluation process. The use of Checklist C supports such verification by summarizing the major issues of the innovation according to four areas of concerns: attributes, effects, compatibility, and feasibility. The checklist also contains a set of practical implementation requirements for the innovation. By addressing these requirements, the evaluation team revises implementation strategies and does the groundwork for the final implementation plan (developed in Step 9). This task results in all the development of a report that summarizes all main characteristics and implications of the considered innovation.
- Having listed all the possible factors relating to the considered innovation, the evaluation team may want to assign weight to each factor or to a set of related issues that address the same concern. Weighting (e.g., merit or relevance) can be based on a one-to-five scale according to your agency's priorities, the circumstances, and the type of innovation. This task facilitates the selection of the final evaluation criteria.
- The last task of Step 7 consists of selecting a suitable set of criteria for evaluation. Ideally, each criterion should incorporate more than one of the factors that have been addressed in the previous steps. Checklist D lists some criteria aimed at this goal. Please note that these

criteria, given their differing characteristics, should be addressed with a combination of qualitative and quantitative measurements in Step 8.

TIPS:

In processing the data for evaluating the innovation, remember the following:

- Data serve as a foundation for action, and, as such, they should represent reality as much as possible. Ideally, data should be structured so that they lead to a reliable measurement and so that the evaluation team agrees the measurement is valid.
- Data reflect quantifiable (e.g., technical) and nonquantifiable (e.g., social or behavioral) factors whose combination and interaction should be considered. Quantifiable data, such as cost or safety, are often major determinants when the implementation of an innovation falls within routine operations, when it can be easily managed within the boundaries of a single DOT unit, and when it involves little or no negotiation outside the unit. Nonquantifiable elements, such as organizational resistance or community concerns, become relevant when implementation entails the cooperation of multiple units or outside stakeholders, or both. In this case, nonquantifiable elements, rather than quantifiable elements, may become a major critical constraint of decision making.
- Quantifiable data are easy to understand. Understanding data becomes more difficult when social, political, behavioral, and managerial-related data are considered. Those people involved must reach a common understanding of the terminology and definitions to be used.
- The values of costs and benefits and other performance criteria are predicted. They result from a process by which the positive and negative effects of any innovation are discovered and estimated. This set of predictions is the input for Step 8, whose success depends also on the reliability of these predictions. Ideally, some indication of the confidence that can be placed in the prediction should be given.

TOOLS:

- Checklists
- Expert opinion
- Group discussion and consensus

REFERENCES:

- *NCHRP Synthesis of Highway Practice 48: Priority Programming and Project Selection.* Transportation Research Board, National Research Council, Washington, D.C., 1978.
- Brand, D. "Criteria and Methods for Evaluating Intelligent Transportation System Plans and Operational Tests." *Transportation Research Record 1453*, Transportation Research Board, National Research Council, Washington, D.C., 1994, pp. 1–15.

Checklist C: Verify Raised Issues

Gathered Documentation

			Comments
Technical characteristics	A	NA	
Meets specifications (AASHTO, ASTM, Federal, etc.)	A	NA	
Test results	A	NA	
Implementation results (other DOTs)	A	NA	
Other sources	A	NA	

Preliminary Assessment (Step 1)

Effects/benefits			Comments	Wt.
Reduced cost/time, better performance/cost ratio	A	NA		
Increased safety	A	NA		
Better ridership	A	NA		
Greater efficiency	A	NA		
Greater convenience	A	NA		
Improved conditions (e.g., reduced pollution, energy consumption)	A	NA		
Aesthetics	A	NA		

Fit

DOT's mission and strategic plan	A	NA		
Customers' needs or problems	A	NA		

Feasibility

Integratability into DOT's existing procedure and practice	A	NA		
Environmental-related issues	A	NA		
Regulatory and legislative issues	A	NA		

Desirability

In relation to other innovation opportunities	A	NA		
Scope of application/use	A	NA		
Implementation potential	A	NA		
Estimated cost/required performance	A	NA		

Characteristics of the Innovation (Step 3)

Technology issues

			Comments	Wt.
Within existing technological and know-how tradition	A	NA		
Radical change from existing technological and know-how tradition	A	NA		
Divisibility (phased or piecemeal adoption)	A	NA		
Adaptability (to users' needs)	A	NA		
Proprietary/patented technology	A	NA		

Performance issues

Previous testing and validation	A	NA		
Reliability of performance data	A	NA		
Possibility of pilot projects	A	NA		
Implementation package and/or support is included with innovation	A	NA		

Effects of the Innovation (Step 4)

Within the DOT

			Comments	Wt.
Benefits from the use of innovation	A	NA		
Possible limitations	A	NA		
Need for modified or new work procedures, standards, and specs	A	NA		
Cost of implementation and sustainability	A	NA		
Effect on personnel jobs and motivation	A	NA		
Strategic positioning of the agency	A	NA		

Outside the DOT

Public image of the agency	A	NA		
Benefits for road users	A	NA		
Effect on surrounding communities	A	NA		
Effect on local industry	A	NA		
Environmental impact	A	NA		
Any possible risks associated with the use or failure of the innovation	A	NA		

Compatibility of the Innovation with the DOT's Resources (Step 5)

			Comments	Wt.
Compatibility with existing work procedures, standards, and specs	A	NA		
Availability of targeted funding	A	NA		
Availability of technical capabilities	A	NA		
In-house capability to maintain the innovation after implementation	A	NA		
In-house feedback and improvement after implementation	A	NA		
Availability of outside providers during and after implementation	A	NA		

Feasibility of Implementation (Step 6)

Implementation issues			Comments	Wt.
Cost-effectiveness of implementation	A	NA		
Departments/user groups affected	A	NA		
Acceptability to local interest groups and the public	A	NA		
Acceptability to regulatory and funding agencies	A	NA		
Support by stakeholders, DOT units, and users groups	A	NA		
Resistance to implementation and possible solutions	A	NA		
Environmental concerns have been addressed	A	NA		
Legal/regulatory concerns have been addressed	A	NA		
Top management involvement	A	NA		

Potential contingencies of implementation

Need for cooperation between provider and agency	A	NA		
Need for coordination with other research activities	A	NA		
Need for coordination with other authorities during and after implementation	A	NA		
Risk associated with implementation failure	A	NA		
Beneficiaries and communities during implementation	A	NA		

Implementation Requirements (Step 9)

Actions/tools			Comments	Wt.
Workshops	A	NA		
Lab tests	A	NA		
Training/orientation	A	NA		
Pilot project(s)	A	NA		
Publications: reports, newsletters, research briefs, specs, and standards	A	NA		

Human resources requirements

Champion/advocates	A	NA		
Implementers/key personnel	A	NA		
—Technical capabilities	A	NA		
Key decision makers	A	NA		
—Technical level (commitment)	A	NA		
—Political level (acceptability)	A	NA		
—Management turnover	A	NA		
Other stakeholders (outside agency)	A	NA		
—Acceptability/cooperation	A	NA		
Implementation committee	A	NA		

Control/feedback requirements

Control/advisory panel	A	NA		
Communication system	A	NA		
—Workshops	A	NA		
—Reports/accountability	A	NA		

Cost and time of implementation

Cost of implementation	A	NA		
Cost-effectiveness after implementation	A	NA		
Time for implementation	A	NA		

Checklist D: Develop Evaluation Criteria

Short- and long-term costs			Comments	Wt.
Cost of implementation	A	NA		
Cost of sustained use	A	NA		
Other costs	A	NA		

Short- and long-term benefits				
Increased operational efficiency (e.g. savings, personnel time, etc.)	A	NA		
Increased safety	A	NA		
Decreased pollution	A	NA		
Reduced energy usage	A	NA		
Reduced social cost (e.g. delays, congestion, etc.)	A	NA		
Other benefits	A	NA		

Ease of implementation				
Technical feasibility	A	NA		
Availability of funding	A	NA		
Availability of in-house technical and management services	A	NA		
Acceptability to key decision makers, stakeholders, and the public	A	NA		
DOT's commitments	A	NA		
Technology adaptability/flexibility	A	NA		
Other appropriate criteria	A	NA		

STEP 8: APPLY EVALUATION METHODS

OBJECTIVES:

- To undertake a formal evaluation of the innovation.
- To decide whether the innovation should be implemented.

KEY ACTIVITIES:

- Group the listed criteria according to information contents, from qualitative to quantitative data.
- Apply evaluation methods.
- Verify the results of the evaluation.
- Decide whether to proceed with an implementation plan.

INPUTS:

- Results of Step 7.
- See Tools for Evaluation Process.
- Agency protocols.

QUESTIONS/ISSUES:

- As previously stated, the defined evaluation criteria pose issues that are answered in different ways. Some issues, such as "acceptability," can be considered in terms of positive or negative answers. Other factors, such as technical feasibility, are answered in relative terms, from high to low probability of success. Other issues, such as costs, are answered in numerical terms. The criteria listed in Checklist D can be grouped according to the following evaluation methods:
  - A checklist that summarizes criteria in qualitative terms.
  - A scoring model that attempts to quantify and measure some of the criteria identified in the checklist.
  - A cost-benefit analysis that assesses some of the criteria that cannot be fully measured with scoring models.
- These techniques are used with different precision/quantification levels of information and complement each other. They cannot be used in isolation and are not designed to take the place of the decision maker's judgement—they simply organize information.
- Evaluation through a checklist is advantageous when factors such as environmental concerns, social effects, or political constraints are difficult to quantify and not suitable to be measured with the other two methods.
- A scoring model builds upon some of the quantifiable factors of the checklist and measures what the checklist presents qualitatively. The increased precision of the method requires increased information input. The use of a scoring model consists of assigning weights and scores to each considered evaluation criterion.
- Cost-benefit analysis is a strictly quantitative method, and it covers only a few of the factors of the checklist. More information on the three methods listed above is contained in Part II: Tools for the Evaluation Process.

- The results from the application of cost-benefit analysis can be assessed and verified with two techniques: sensitivity analysis and risk analysis. The first technique, sensitivity analysis, analyzes the sensitivity of results to critical assumptions affecting costs and benefits and helps the evaluators ascertain if more sophisticated analysis is merited for the critical factors. The second technique, risk analysis, identifies the probability distribution of the identified critical variables and helps the evaluators assess the variable's effect on the economic results of the implemented innovation.

The formal evaluation effort assumes that the set of predictions is available at the beginning of Step 8, although some predictions or estimates must be performed in Steps 1, 4, and 5. In practice, the evaluation is likely to have a feedback effect by revealing the need for additional information or new issues that stimulate efforts to predict consequent effects or to define implications.

The last break-in point of the evaluation process follows Step 8. The evaluation team reaches a consensus on whether the innovation deserves to be implemented, whether other resources should be committed, or whether other courses of action should be undertaken.

TIPS:

- The evaluation of a single innovation project may create initial concern in the absence of cut-off or benchmark criteria. This concern can be mitigated by comparing the proposed innovation with existing conditions, such as the system, process, or product whose replacement is considered.
- The practicality of the information contained in a checklist can be improved by pairing each criterion with a judgmental term. For example, a Likert scale (from one to five) can describe the level of satisfaction with criteria, such as resource compatibility, management commitment, availability of suppliers, and political and management support.
- One of the criticisms leveled against techniques such as scoring and cost-benefit analysis is the possibility of bias [e.g., the selection of an arbitrary weight (scoring) or of a too conservative discount rate (cost-benefit analysis)]. In order to ensure objectivity, decisions about each critical evaluation variable should be based on group consensus.

TOOLS:

- Checklists
- Cost-benefit analysis
- Expert opinion
- Peer discussion and consensus
- Risk analysis (not discussed in Part II: Tools for the Evaluation Process)
- Scoring models
- Sensitivity analysis

REFERENCES:

- Merrifield, D. B. *Evaluating R&D and New Product Development Ventures: An Overview of Assessment Methods*. Center for the Utilization of Federal Technology, National Transportation Information Services, U.S. Department of Commerce, 1986.
- Bronitsky, L., and J. Misner. "A Comparison of Methods for Evaluating Urban Transportation Alternatives." *Urban Mass Transportation Association*, UMTA 7410–7411, No.75-5, 1975.

STEP 9: PLAN FOR IMPLEMENTATION

OBJECTIVE:

- To develop the implementation plan of the considered innovation.

KEY ACTIVITIES:

- Describe the specific goals and expected results and milestones.
- Define the specific action steps for achieving results.
- Develop a time line of actions.
- Establish responsibilities and roles for each action.
- Define resource requirements.
- Plan for the communication process.
- Plan for the review and monitoring process.

QUESTIONS/ISSUES:

- Every effective decision-making process should lead to a course of action. Assuming the innovation has been evaluated positively, the next step is to plan for its implementation. Ideally, the same people who served as members of the evaluation team should do this activity. The implementation plan should build upon:
  - A shared agreement among the key decision makers.
  - Provision for the necessary guidance and resources for implementation.
  - Substantial support from those who can strongly affect implementation.
  - A widely shared commitment about the substance of innovation.
- Checklist E suggests a set of steps for the implementation plan.

TIPS:

According to Bryson (*3*), effective ways to design an implementation plan are

- To involve key decision makers, implementers, and (perhaps) representatives of external stakeholder groups in the evaluation of a set of activities using a common set of criteria.
- To maintain and develop a coalition of implementers, advocates, and interest groups who are intent on implementing the changes and are willing to protect them over the long haul.
- To make sure that the legislative, executive, and administrative policies and actions facilitate rather than impede implementation. Consider the need for adequate public-relation resources.
- To recognize that the changes entail changes in the organization's culture.

- To develop shared meanings. When changes are involved, people must be given an opportunity to develop shared meanings and intents that will improve the probability of implementation success. These meanings will both guide and flow out of implementation activities.
- To allow a period of start-up time during implementation in which people can learn about the adopted changes and engage in any necessary retraining, debugging, and development of new norms and operating routines.
- To organize data. In preparing the plan, you may want to organize data according to Table 3:

TABLE 3 Organizing data for an implementation plan

Action to be taken	Person responsible	Expected completion	Actual completion	Resources needed	Other comments

TOOL:

- Action plans

REFERENCES:

- Bryson, J. M. *Strategic Planning for Public and Nonprofit Organizations.* Revised edition. Jossey-Bass Publishers, San Francisco, 1995.
- Bryson, J. M., and F. K. Alston. *Creating and Implementing Your Strategic Plan.* Jossey-Bass Publishers, San Francisco, 1996.

Checklist E: Guidelines for the Implementation Plan of the Innovation

The following guidelines were adapted from *Strategic Planning for Public and Nonprofit Organizations* (*4*):

1. Description of the specific goals and expected results and milestones
2. Specific action steps for achieving results
3. Time line of actions
4. Responsibilities and roles for each action
5. Resource requirements
6. Communication process
7. Review and monitoring process

Guideline 1: Description of the Specific Goals and Expected Results and Milestones

- State the changes you hope to see implemented.
- State the results that the changes will produce in regard to a present need or situation.
- Identify the target clientele, the users of the innovation.

Guideline 2: Specific Action Steps for Achieving Results

- List the action steps to be taken (workshops; lab tests; demonstration projects; training and orientation; pilot projects; and publications, such as reports, newsletters, research briefs, specifications, and standards).
- Describe the functional elements of the plan.
- Indicate who controls these elements directly or indirectly.
- Define indicators to verify performance progress at milestones.
- Identify the assumptions that are key to the success of the implementation plan.

Guideline 3: Time Line of Actions

- Determine start and finish of each action.
- Mark date of milestones.
- Review meeting schedules.

Guideline 4: Responsibilities and Roles for Each Action

- Identify the individuals/groups/units to be involved in implementation (e.g., testing, pilot projects, workshops, and dissemination of information).
- Define the role and composition of advisory/review committee(s).

Guideline 5: Resource Requirements

- Champion/advocates
- Implementers/key personnel (technical capabilities, delegation, and empowerment)
- Key decision makers at the technical level (commitment) and at the political level (acceptability)
- Other stakeholders (outside the agency): acceptability/cooperation
- Advisory/review committee(s)
- Additional staff as needed
- Training and orientation
- Technical assistance
- Inside and outside consultants
- Incentives to facilitate adoption of the changes by relevant units and individuals
- Unforeseen contingencies (e.g., redundancy in case of management turnover)
- Cost of implementation

Guideline 6: Communication Process

- Clarify innovation benefits and implementation goals.
- Identify groups or individuals that need to receive implementation information and updates.
- Identify what information these groups or individuals need.
- Determine criteria according to which such information can be communicated most effectively (e.g., memo, meetings, orientation workshops).
- Determine the timing and cost of information dissemination.
- Identify the personnel responsible for information dissemination.

Guideline 7: Review and Monitoring Process

- Conduct retrospective evaluations to determine whether milestones or interim results have been achieved.
- Review final results and feedback for improvement.
- Determine the cost of the review and monitoring process.

SOURCES CITED IN PART I

1. North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Guide*. NCDOT, 1997.

2. Bryson, J. M. *Strategic Planning for Public and Nonprofit Organizations*. Revised edition. Jossey-Bass Publishers, San Francisco, 1995.

3. Bryson, J. M. *Strategic Planning for Public and Nonprofit Organizations*. Revised edition. Jossey-Bass Publishers, San Francisco, 1995.

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PART II

TOOLS FOR THE EVALUATION PROCESS

OVERVIEW OF TOOLS

This part of the guidelines describes a set of 10 tools to be used during the implementation of the evaluation process. The tools are

1. Action plans
2. Cause-and-effect diagrams
3. Checklists
4. Cost-benefit analysis
5. Expert opinion
6. Group discussion and consensus
7. Influence diagrams
8. Scoring models
9. Sensitivity analysis
10. SWOT analysis

Following is a brief description of these tools.

- **Action plans** state how to implement a general objective or a strategy in the short term. They outline expected results, action steps, personnel responsible for each step, time schedules, and resources requirements.
- **Cause-and-effect diagrams,** which are graphical charts, illustrate the relationship between an outcome (effect) and all the other factors (causes) that produce the outcome. These cause-and-effect diagrams help decision makers in tracing the possible causes of a problem and are also used to identify the factors that are necessary for successful implementation of solutions (*1*).
- **Checklists** are the simplest forms of project evaluation. They consist of a list of questions or criteria that are likely to determine the project's success or failure. They are also used to systematically display and compare data and information for problem analysis. Checklists are the first step for developing scoring models, which quantify what checklists present qualitatively.
- **Cost-benefit analysis** is used to determine the net effect of a given investment on the overall welfare of society. With this tool, all relevant economic costs and benefits associated with the life cycle of an investment (e.g., a project or an innovation) are included. Where possible, all the noneconomic costs and benefits (e.g., air quality or quality of life) are converted into equivalent economic values (e.g., dollars). The tool is effective in comparing alternative solutions (e.g., comparing the benefits and costs of existing conditions with those of a considered innovation).

- **Expert opinion**—the opinions of people who are knowledgeable about the particular field in which the innovation is being applied—gauges the importance of the innovation and its probable usefulness and effect (*2*).
- **Group discussion and consensus,** a highly interactive process, enables team members to reach agreement among themselves. This tool is used for brainstorming ideas and for reaching a collective decision during problem solving (*3*).
- **Influence diagrams** provide a simple graphical representation of decision-making situations by structuring the elements contained within: decisions and alternatives, uncertain events and outcomes, and consequences.
- **Scoring models** build upon the criteria that have been previously developed with checklists. These criteria are quantified rather than presented qualitatively, as in the case of checklists. Because of their increased precision, scoring models require more information input.
- **Sensitivity analysis** answers "what if" questions (i.e., the effect of change in one or more factors that characterize the economic evaluation of a project). The analysis helps decision makers identify factors and assumptions that are sensitive to changes and may alter significantly the overall expected economic performance of a project. Thus, sensitivity analysis helps decision makers assess the effect of uncertainty in a project.
- **SWOT analysis** is used to examine the strengths, weaknesses, opportunities, and threats that characterize an organization. The analysis clarifies the conditions in which an organization operates. In this regard, SWOT analysis can be useful in evaluating innovations, particularly those requiring substantial organizational adjustments and investment of resources.

Evaluation activities are based on an informative process that consists of (a) data generation and interpretation; (b) data assessment and representation (structuring data); and (c) data measurement (assigning qualitative and quantitative values to these data). In this context, the suggested timing of the above-described tools during the evaluation process is as follows:

- Data generation and interpretation: expert opinion, group discussion and consensus, and SWOT analysis.
- Data assessment and representation: cause-and-effect diagrams, checklists, and influence diagrams.
- Data measurement: cost-benefit analysis, scoring models, sensitivity analysis, and checklists.

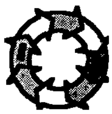
In practice the tools are used throughout the process, given the iterative nature of the process' activities. The only exceptions are the cost-benefit and sensitivity analyses that are used in Step 8. In addition to being used in Step 9, action plans also can be used in Step 2 for planning the evaluation activities for the considered innovation.

Each evaluation-related tool is presented according to the following criteria:

OBJECTIVE

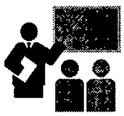
A brief description of the tool and its characteristics.

PROCESS



A detailed description of the steps for using the tool.

EXAMPLE

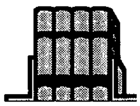


When possible, an example is included to demonstrate the use of the tool.

TIPS

Considerations and recommendations for the effective use of the tool.

REFERENCES



References for use of the tool.

ACTION PLANS

OBJECTIVES:

An action plan is a detail-oriented technique that documents and organizes the schedule, events, activities, and responsibilities for the steps necessary to complete a project, to solve a problem, or to implement an organizational strategy (*4*). Action plans are useful in coordinating team efforts and scheduling any team project. They are also useful in helping the team explain its implementation or evaluation plan to management and other individuals involved. An action plan can be organized or formatted in many different ways, but all action plans should answer the following questions: *who, what, when, where*, and *how*.

PROCESS:

1. Analyze the process and break it down into achievable steps.
2. Consider the number of people and other resources involved at each step.
3. Identify any additional factors that will affect the completion of each step in the process. (The team may consider brainstorming to develop a list of significant factors.)
4. Select a team member (or members) to be responsible for each step.
5. Determine how long each step will take and set a realistic completion date.
6. Include any assumptions on which the plan is based and clearly label the plan.
7. Monitor progress using the schedule in the action plan.
8. Follow the project through its completion.

EXAMPLE:

An action plan outlines

- Specific expected results and milestones,
- Responsibilities of individuals and agency units,
- Specific action steps,
- Schedules,
- Resource requirements and sources,
- The communication plan, and
- The review and monitoring process.

Some of these issues are reflected in Table 4:

TABLE 4 Action plan

Action to be taken	Person responsible	Expected completion	Actual completion	Resources needed	Other comments

TIPS:

- An action plan can be used by individuals, groups, or teams.
- An action plan may be as detailed as needed to ensure that all the desired objectives are accounted for in the plan.

REFERENCES:

- Bryson, J. M. *Strategic Planning for Public and Nonprofit Organizations*. Revised edition. Jossey-Bass Publishers, San Francisco, 1995.
- Bryson, J. M., and F. K. Alston. *Creating and Implementing Your Strategic Plan*. Jossey-Bass Publishers, San Francisco, 1996.

CAUSE-AND-EFFECT DIAGRAMS

OBJECTIVES:

Cause-and-effect diagrams—also known as fishbone diagrams—are graphical charts that illustrate the relationship between an outcome (effect) and the factors (causes) that produce the outcome (*5*). The cause-and-effect diagram helps decision makers to trace the possible causes of a problem, helps teams to reach a common understanding of problems, and exposes gaps in existing knowledge. These diagrams are also used to identify the factors that are necessary for successful implementation of solutions.

PROCESS:

1. Draw a blank fishbone (cause-and-effect) diagram.
2. Identify the main problem and label the fish head.
3. Identify all the major categories of potential causes of the problem by brainstorming.
4. Place these categories on the fishbone. The most likely causes of the problem are placed near the head, and the less likely causes of the problem are placed away from the head nearer the tail.
5. Break down each major category into factors that contribute to that cause.
6. Record these factors on the fishbone.
7. Collect data that support or disprove each possible cause of the problem. (This could be done using checklists, interviews, and so forth.)

EXAMPLE:

Consider the analysis of the reasons for a delay in filling supply orders, as shown in Figure 2.

1. Draw a blank fishbone diagram.
2. Label the head of the fish "Delay in supply."

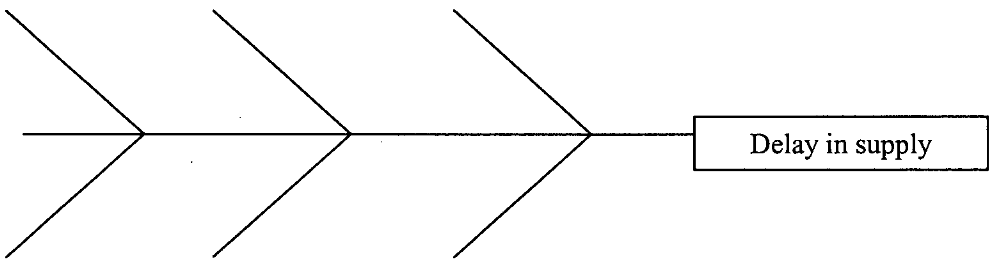


Figure 2. Labeling the problem in fishbone (cause-and-effect) diagram.

3. Categorize the possible causes for the delay:
   - Not enough staff
   - Supplies not on hand
   - Order never picked up
   - Order not completed
4. Place the most likely causes of the delay near the head; position the others according to their importance and likelihood, as shown in Figure 3.

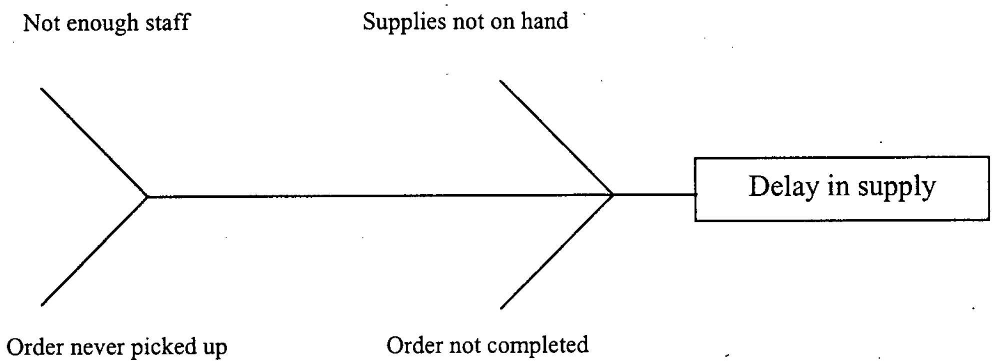


Figure 3. Labeling causes in fishbone (cause-and-effect) diagram.

5. Identify the specific factors contributing to each category of cause. For example, consider "orders not on hand." Things that could have gone wrong are:
   - Order not processed
     * Caused by a budget shortage
   - Vendor delayed
6. Plug the likely factors into the diagram, as shown in Figure 4.

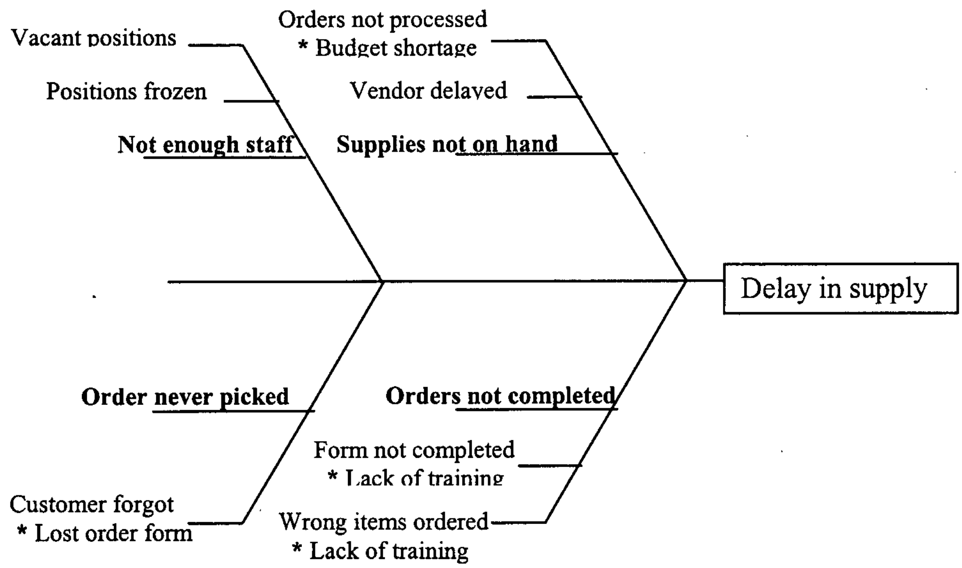


Figure 4. Labeling factors in fishbone (cause-and-effect) diagram.

The diagram displays all the possible causes of delay in supply. The organization can then try to minimize or eliminate these causes to reduce the occurrence of delays. At this point, the analysis of the remedies for the causes can start. Efforts for minimizing or eliminating the possible problems are considered.

TIPS:

- A cause-and-effect diagram is used to identify possible causes of problems and, consequently, to raise issues that also deserve analysis.
- The identification of the causes of the problem should be followed by an action plan that addresses the problem.
- The most common causes are people, machines, materials, methods, and the environment.
- Only causes should be listed, not symptoms.
- Factual data must be collected to verify or validate possible root causes.

REFERENCE:

- North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Toolbox.* Version 1.0. NCDOT, 1997.

CHECKLISTS

OBJECTIVES:

A checklist is the simplest form of project evaluation. It consists of a list of questions or criteria that are likely to determine the project's success or failure. It is also used to systematically display and compare data and information for problem analysis.

In the case of an innovation project, a checklist generally includes technical, economic, environmental, legal, and organizational considerations. This tool is flexible and simple to apply. It is useful for the initial screening of an innovation and for deciding whether to proceed with an innovation's formal evaluation. A checklist can also be used to compare two innovation alternatives against a chosen set of evaluation criteria.

Checklists are also the first step for developing scoring models, which quantify what the checklists present qualitatively.

PROCESS:

1. Gather and organize all the information to complete the task in question.
2. Select a set of criteria that are crucial for the failure or success of a considered innovation option(s).
3. List these criteria, avoiding duplication.
4. Question each criterion and update according to team input.
5. Consider the innovation option according to each criterion.
6. Reject the option if it does not fulfill the criteria.

EXAMPLE:

Consider the case of a transportation agency that screens a potential innovation project:

1. Does the innovation offer opportunities for performance improvement?	Y	N
2. Does the innovation meet the needs and the mission of the agency?	Y	N
3. Is the implementation compatible with existing procedures?	Y	N
4. Does the agency have the resources for implementing the innovation?	Y	N
5. Is the innovation cost-effective?	Y	N

The number of criteria can be increased according to the priorities or constraints of the agency. The issue posed by each criterion is addressed with a positive or negative answer. An "Undecided" category (U) can be added if the issue needs further consideration or information.

TIPS:

- There is no correct or incorrect method of preparing a checklist.
- Using checklists at the screening stage can help save time and effort in evaluating projects that do not meet predefined requirements.
- A checklist can be used as a tool for defining what type of information is needed for the assessment of an innovation.

REFERENCES:

- Merrifield, D. B. *Evaluating R&D and New Product Development Ventures: An Overview of Assessment Methods.* National Transportation Information Service, U.S. Department of Commerce, 1986.
- North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Toolbox.* Version 1.0. NCDOT, 1997.

COST-BENEFIT ANALYSIS

OBJECTIVE:

Cost-benefit analysis is used to determine the net effect of a given investment on the overall welfare of society. With this tool, all relevant economic costs and benefits associated with the life cycle of an investment (e.g., a project or an innovation) are included. All the noneconomic costs and benefits (e.g., air quality or quality of life) are converted into equivalent economic values (e.g., dollars). The tool is effective in comparing alternative solutions and selecting the most cost-effective one.

Cost-benefit analysis allows an evaluation team to discover all the known costs and benefits associated with an innovation. The analysis also helps in deciding whether to implement a given innovation.

PROCESS (*6*):

1. A brainstorming process is used to decide on both the direct and indirect costs that are associated with a proposed solution.
2. Cost is assigned to each factor being considered. For indirect costs (e.g., personnel, equipment), a percentage of "utilization" or a best estimate is used.
3. Recurring costs and one-time costs are separated. This helps in determining the costs after the first year.
4. Benefits data are calculated and recorded. For indirect or intangible benefits, a percentage or best estimate is used.
5. A chart is built to track all the yearly costs and benefits over the evaluation period (e.g., 5–10 years). The costs and benefits for each year and life cycle are then compared.
6. The data are then analyzed to answer the following questions:
   - How soon will benefits exceed costs?
   - How much can be saved over the evaluation period?
   - What is the associated benefit-to-cost ratio?
   - Based on data recorded, should this solution be considered further?

EXAMPLE (*7*):

The Carquiñez Bridge electronic toll collection (ETC) system was a pilot project undertaken by California Department of Transportation (Caltrans) in 1997 to improve service on the state's toll bridges. Benefit-cost analysis was used to evaluate the feasibility of the project. Following is a description of the economic evaluation process. Historical data on traffic volume at the bridge were collected from Caltrans and from existing national statistical sources. The data were used to estimate future annual traffic demand, direct costs, and benefits over the 10-year evaluation period. Reasonable assumptions were made for calculating traffic growth, market share of ETC usage, toll transaction time by type of payment, travel speed, and the design configuration of the bridge.

Some of the assumptions made in planning the system are shown in Table 5:

TABLE 5 Carquiñez Bridge electronic toll collection system assumptions

Annual traffic growth rate	3%
Annual growth rates of ETC transactions	FY 97/98–6% FY 98/99–15% Thereafter–5% annually
Seconds per cash transaction	10
Seconds per ticket transaction	4.5
Seconds per ETC transaction	2.4
Normal travel speed	55 mph
Ramp distance to and from toll plaza	0.2 miles

The quantifiable costs and benefits of the system were grouped into five major categories:

1. *Direct monetary costs or savings.* These were changes in the operating revenues and life-cycle expenses of toll services and vehicles.
2. *Costs and savings associated with traffic accidents.* These were categorized as follows:
   - Costs to users from accidents, such as vehicle repairs, medical expenses, wage losses, and expenditures from personal injury and death.
   - Costs to toll agencies from traffic accidents, such as resources used for repairing property damage caused by traffic accidents.
   - Community costs in support services, such as police, emergency services, and insurance services provided by other sectors of society.
3. *Time costs and savings.* Time cost is the time spent by users while using toll services.
4. *Environmental costs or savings.* This refers to community expenditures to repair any environmental damage.
5. *Items not included in the previous categories.* This includes other nonquantifiable benefits such as an increase in travel convenience; data collection; improvements in data quality and service quality; and other effects on travel demand, traffic congestion, productivity, and so forth.

In addition to the assumptions shown in Table 5, other assumptions were made during the planning of the bridge's ETC system. These included:

- The toll agency bore the cost of the equipment.
- An hourly time value of $12.75 for auto and bus travelers and of $33.41 for truck drivers was assumed.
- The system life span was assumed to be 10 years, equal to the life of ETC components.
- The effects of the ETC system were limited to the bridge itself. No effect on alternative routes was assumed, since the bridge is geographically isolated from other bridges and highways.

- The sum and distribution of the direct costs, benefits, benefit-to-cost ratio, and net benefits during the evaluation period were calculated for the various parties involved.

The results of cost-benefit analysis are shown in Table 6:

TABLE 6 Cost-benefit analysis of Carquiñez Bridge electronic toll collection system (dollars in thousands discounted to fiscal year 1995)

	Total	Toll agency	ETC users	Community
Direct costs	$2,885	$2,543	$342	$0
Benefits	$13,664	$342	$13,299	$23
Benefit-to-cost ratio	4.7	0.1	38.9	N/A
Net benefits	$10,779	–$2,201	$12,957	$23

The findings of the cost-benefit analysis are as follows:

1. Overall, the ETC would result in a net present value of $11 million and a benefit-to-cost ratio of 4.7 over the 10-year evaluation period. Thus, the project was considered acceptable.
2. Distribution of direct costs and net benefits is uneven. The ETC users benefit the most, with a net benefit of about $13 million in FY95 dollars.
3. Although the ETC system would save the toll agency labor and operation cost in later years, it would cost the agency $2.2 million in constant dollars during the evaluation period.
4. The ETC would also generate environmental benefits for the community, although of a relatively small magnitude.

TIPS:

- The list of costs and benefits should be comprehensive. The list may be generated by brainstorming.
- When proposing a product, machinery, equipment, facilities, or other items with a limited life, the calculation should be made for the entire useful life of the equipment.
- Care should be taken to assign proper economic value to nondirect costs and benefits.

- All costs and benefits identified in economic terms should be converted into present values using proper inflation and discount rates. Calculations are based on the following formulas:

$$\text{Present value} = \text{Future value/Present value factor}$$
$$\text{Present value factor} = [1 + r]^n$$

where

r = the discount rate, and
n = time (years) in which future benefits or costs are incurred.

- Costs and benefits that cannot be expressed monetarily should be noted, so they are not forgotten when evaluating alternatives.

REFERENCES:

- Bronitsky, L., and J. Misner. "A Comparison of Methods for Evaluating Urban Transportation Alternatives." *Urban Mass Transportation Association*, UMTA 7410–7411, No.75-5, 1975.
- Federal Highway Administration. "Exploring the Applications of Benefit/Cost Methodologies to Transportation Infrastructure Decision Making." *Searching for Solutions*, FHWA-PL-96-014, No. 16, July 1996.
- North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Toolbox*. Version 1.0. NCDOT, 1997.
- Williams, D. *TAC Synthesis of Practice Series No. 4: Performance Evaluation Mechanisms for Transportation Research Programs*. Transportation Association of Canada, 1996.

EXPERT OPINION

OBJECTIVE:

Expert opinion—the advice of people who are knowledgeable about the particular field in which the innovation is being applied—gauges the importance of the innovation and its probable usefulness and effect. Experts can be either internal or external to the organization, such as academicians and consultants.

Although expert opinion can be solicited at any time in the evaluation process, it is most commonly solicited at the beginning of the process when a potential innovation is being considered. Experts use their knowledge, experience, and sometimes "gut feelings" to evaluate an innovation. Experts may also suggest issues that were overlooked during the evaluation process.

PROCESS:

With this tool, the experts are decision makers—they collect data regarding the characteristics and predicted effects of the innovation being considered. Decision makers weigh the data as they think appropriate and evaluate the relative merits and demerits of alternatives. They may ignore some data and regard other data as completely decisive. The decision calls for a judgment by the decision makers.

Modified peer review is a commonly used expert-opinion method. In traditional peer review, the scientific merit of the research is assessed by experts or peers in the specific research field. Modified peer review asks peers to address both the scientific aspects and social impacts of a research project.

TIPS:

- The tool offers the advantage of obtaining high-quality information about the potential usefulness and effect of an innovation with relatively little effort.
- More than one expert is generally used in order to minimize possible individual biases.

REFERENCES:

- Williams, D. *TAC Synthesis of Practice Series No. 4: Performance Evaluation Mechanisms for Transportation Research Programs*. Transportation Association of Canada, 1996.
- Bronitsky, L., and J. Misner. "A Comparison of Methods for Evaluating Urban Transportation Alternatives." *Urban Mass Transportation Association,* UMTA 7410–7411, No.75-5, 1975.

GROUP DISCUSSION AND CONSENSUS

OBJECTIVE:

This tool is a highly interactive process that enables team members to reach agreement among themselves. Group discussion and consensus is used for brainstorming and for reaching a collective decision during problem solving. It recognizes that all team members may not fully agree with a decision, but based on the best information available, they can support the decision (*8*).

PROCESS:

In group meetings, individuals with different expertise discuss the pros and cons of an innovation. These individuals typically represent the agency's units and other stakeholders who are affected by the innovation. The objective of the meetings is to bring the group to a final decision—people extensively discuss the issue at hand until a common agreement or consensus is reached.

Discussion should be characterized by open communication, active participation, and, above all, open-mindedness (the ability to support a decision made by the group despite differing personal viewpoints). If necessary, an outside facilitator can be used for conflict resolution.

If consensus cannot be achieved openly, voting is used for promoting popular ideas and issues and for eliminating unpopular ones.

TIPS:

- Peer discussion should be used when problem solving requires active involvement from several groups or individuals. No one person has the expertise to make the right choice.
- The peer consensus-building process has some limitations, such as
  - Strong individuals may dominate the session, overshadowing the ideas of other people; consequently, group discussions should be properly conducted to ensure free flow of ideas.
  - Some important ideas may be lost in the overall confusion of a session.
  - Since the exchange of ideas is not anonymous, people may not be willing to express their concerns.

REFERENCE:

- North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Toolbox.* Version 1.0. NCDOT, 1997.

INFLUENCE DIAGRAMS

OBJECTIVE:

Influence diagrams provide a simple graphical representation of decision-making situations by structuring the elements contained within: decisions and alternatives, uncertain events and outcomes, and consequences. In the diagram, different decision elements show up as different shapes, which are then linked with arrows to show logical relationships among the elements.

PROCESS:

1. Use rectangles to represent decisions and ovals to represent chance events; a rectangle with rounded corners is used to represent mathematical calculations, constant value, consequences, and a variety of other elements.
2. Start the influence diagram with the decision to be made.
3. Introduce all the factors that will affect the decision.
4. Draw the likely outcome(s) of the decision.
5. Introduce the factors that will affect the outcome(s).
6. Add the follow-up decisions that could be made as the result of various outcomes.
7. Repeat steps 3–6 for each decision.

EXAMPLE:

An agency is considering the introduction of a toll highway.

The agency's objective is to maximize net benefits in terms of time-savings for commuters, improved service, and so forth. This objective is made into a consequence node labeled "Net benefit." Initially, both cost and benefits may be uncertain. Consequently, the first version of the diagram might be as shown in Figure 5:

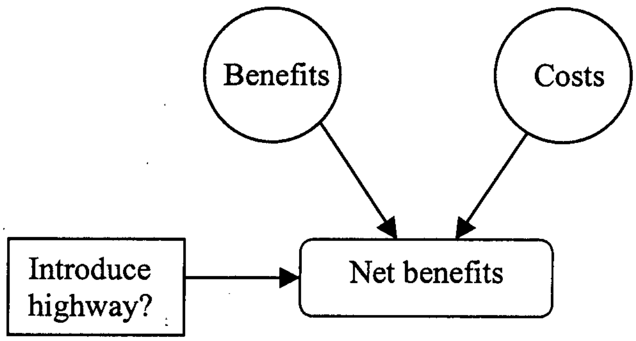


Figure 5. Initial influence diagram for toll highway.

To incorporate the uncertainty of variable costs (e.g., such as different forms of financing), costs are broken down into fixed (e.g., construction) and variable costs. If travelers have to pay for using the highway, there is also uncertainty about their effective number. A decision must be made about the toll amount to be charged. Quantification is affected by the need for covering expenses and, at the same time, for ensuring the right size of demand (demand control). These considerations are incorporated as shown in Figure 6:

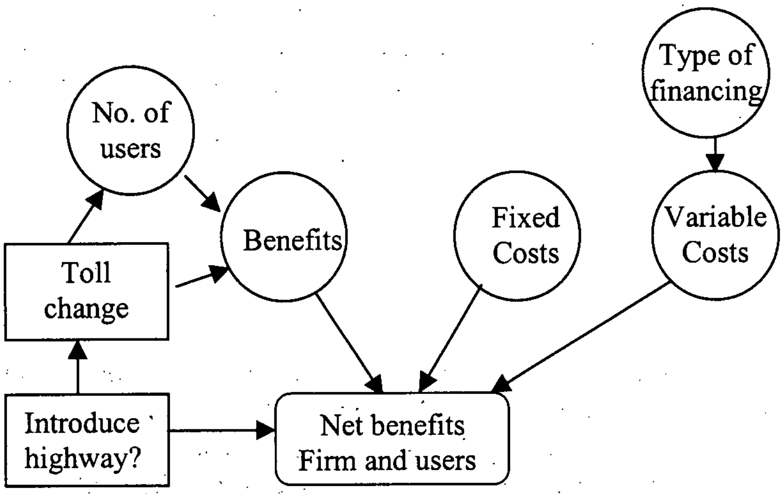
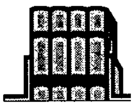


Figure 6. Second influence diagram for toll highway.

TIPS:

- Influence diagrams are not used for solving a problem, but for structuring it.
- Influence diagrams are useful for understanding and representing the structure of a problem, its elements, and the elements' interaction, so that a more informed decision can be made.



REFERENCE:

- Clemen, R. T. *Making Hard Decisions*. Duxbury Press, Belmont, CA, 1996.

SCORING MODELS

OBJECTIVE:

Scoring models build upon the criteria that have been previously developed with checklists. These criteria are quantified rather than presented qualitatively, as in the case with checklists. Because of its increased precision, a scoring model requires more information input. The model can be used for evaluating different innovation options or a given innovation option against the current technology or practice of an agency. The criteria selected for evaluating each alternative can be either treated equally or weighted according to the relative importance that each criterion may have within the full set of considered criteria.

PROCESS:

1. Develop a list of agreed-upon criteria relevant to the evaluation task.
2. Define a scale to be used to rate each considered option (e.g., from 1 to 10).
3. Assign weights to the criteria. This can be done by one of the following methods:
   - *Pair-wise comparison.* Each criterion is compared to the other listed criteria on a one-to-one basis. The comparison is performed on a common scale, so that at the end of the process the relative importance of each criterion is found in quantitative terms.
   - *Number scale.* Assign a number to each criterion that reflects its importance (1 = least important; 10 = most important). The overall weight of each criterion is defined by averaging the values that have been assigned by each member of the evaluation team.
4. Rate each option against each criterion.
5. Multiply each rating by the weight assigned to each option.
6. Sum the points for each option. The highest scoring identifies the best option that can be considered for further evaluation (if necessary).

EXAMPLE (*9*):

Consider the choice among transit alternatives for an urban community.

The alternatives being considered are

- Automated guideway transit (AGT),
- Rail rapid transit, and
- Bus transit.

The various criteria that could be used to evaluate the alternatives are shown in the first column of Table 7.

The weight of each criterion is generated with the pair-wise comparison method. The criteria are compared to one another on a one-to-one basis. The most important criterion is assigned a weight of 10 (in this case, "travel time and level of service"), and the weight is placed in the second column of Table 7. All other criteria are then scaled based on this criterion and assigned a respective weight. For example, if "attracting patronage" is 70 percent as important as "travel time and level of service," then it is assigned a weight of 7.

TABLE 7 Scoring model for urban community transit alternatives

		Bus transit		**Rail rapid transit**		**Automated guide way transit**	
Criteria	**Wt**	Score	Criteria score	Score	Criteria score	Score	Criteria score
Travel time and level of service	10	3	30	10	100	8	80
Attracting patronage	4	2	8	7	28	10	40
Capital cost	7	10	70	4	28	6	42
Operating and maintenance cost	7	8	56	4	28	6	42
Favorable influence of land use/urban development	6	4	24	7	42	10	60
Right-of-way required	4	10	40	4	16	6	24
Energy conservation	6	4	24	8	48	8	48
Improving air quality	6	2	12	10	60	8	48
Noise problems	4	4	16	5	20	10	40
Visual intrusions	2	10	20	6	12	8	16
Reducing the need for auto travel	7	4	28	10	70	7	49
Total Criteria Score			328		452		489

Table 7 shows that after rating each option against the criteria, multiplying each rating by the weight, and summing the points, the AGT alternative is the most desirable option.

TIPS:

- Scoring models require a significant amount of data or information that may not be available at the outset of the evaluation process.
- Although a choice is made on the basis of the resulting final score, the model is merely a tool that does not replace the judgement of the decision maker.
- The overall high scoring of an option may induce an evaluator to overlook some negative aspects (e.g., specific criteria with low scoring). If not properly considered, these negative aspects could affect the project outcome adversely.

REFERENCES:

- Merrifield, D. B. *Evaluating R&D and New Product Development Ventures: An Overview of Assessment Methods*. National Transportation Information Service, U.S. Department of Commerce, 1986.
- North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Toolbox*. Version 1.0. NCDOT, 1997.

SENSITIVITY ANALYSIS

OBJECTIVE:

Sensitivity analysis answers "what if" questions (i.e., the effect of change in one or more factors that characterize the economic evaluation of a project). The analysis helps decision makers identify factors and assumptions that are sensitive to changes and that may alter significantly the overall expected economic performance of a project. Thus, sensitivity analysis helps decision makers assess the effect of uncertainty in a project.

PROCESS:

The total costs and benefits of a project, as well as other factors such as inflation, time, and growth rate, that have been considered in the cost-benefit analysis are the primary inputs of sensitivity analysis. The application of the analysis consists of varying the values, or probabilities assigned to any of the above-mentioned variables, and observing the effect of such a variation on the final outcome of calculations. The analysis can be done by varying either one variable at a time or two variables at a time when done manually. Specific software could be used to vary more than two variables.

EXAMPLE (*10*):

The Carquiñez Bridge ETC project example (discussed in the cost-benefit analysis section) can be used to illustrate this tool. Sensitivity analysis started from the consideration of data developed in the cost-benefit analysis, by assessing the possible effects of changing assumptions on net benefits and on the distribution of benefits and costs.

If the ETC market share were assumed to be 35 percent higher than the original outcome, the total net benefits would be more than double, as shown in Table 8:

TABLE 8 Sensitivity analysis of Carquiñez Bridge electronic toll collection system (dollars in thousands discounted to fiscal year 1995)

Scenario	Total benefits	Toll agency benefits	ETC users benefits	Community benefits
Original assumption	$10,779	–$2,201	$12,957	$23
Change in market share (users pay)	$25,425	$2,488	$22,889	$48
Change in market share (agency pays)	$25,626	–$2,229	$27,807	$48
Change in time value	$7,078	–$2,201	$9,256	$23
Change in fuel consumption	$11,283	–$2,201	$13,446	$38

How net benefits were distributed depended on who paid the cost of ETC transponders. If ETC users bore the costs of transponders, all the groups would be better off. However, if the toll agency bore the cost of the transponders, it would bear a slightly greater financial burden than under the previous scenario.

The original assumptions set the hourly time value at $12.75 for auto and bus travelers and $33.41 for truck drivers. Because this assumption could be overestimated for lack of information on travelers' profiles, a more conservative time value was used: $9.00 per hour for auto and bus travelers and $23.40 per hour for truck drivers. The analysis shows that changing the time value would not change the distribution of net benefits to the agency and community, although it would reduce both total and ETC users' net benefits.

Since fuel savings and emission reduction account for only about 6 percent of the total benefits, changing the assumption about fuel consumption would cause an increase of about 4 percent in total benefits. This change would not have a significant effect on the outcome of benefit estimates or on the distribution of net benefits among the three groups.

TIPS:

- The results should be inferred in such a way as to provide a clear picture of how the considered project stands in terms of sensitivity of factors and their degree of volatility.
- Inferences should provide a complete foundation on which to base decisions.

REFERENCES:

- Clemen, R. T. *Making Hard Decisions.* Duxbury Press, Belmont, CA, 1996.
- Merrifield, D. B. *Evaluating R&D and New Product Development Ventures: An Overview of Assessment Methods.* National Transportation Information Service, U.S. Department of Commerce, 1986.

STRENGTH, WEAKNESS, OPPORTUNITIES, AND THREATS (SWOT) ANALYSIS

OBJECTIVE:

SWOT analysis is used to examine the strengths, weaknesses, opportunities, and threats that characterize an organization. The analysis clarifies the conditions in which an organization operates. Strengths and weaknesses are internal factors, while opportunities and threats are external factors that an organization faces in the foreseeable future. The external factors generally are of a political, legal, economic, social, or technical nature.

SWOT analysis provides information for developing effective strategies that build upon organizational strengths and, at the same time, cope with organizational weaknesses. The analysis is also used to assess the organization's ability to respond to threats and take advantage of opportunities. In this regard, SWOT analysis can be very useful in evaluating innovation, particularly those innovations requiring substantial organizational adjustments and investment of resources.

PROCESS (*11*):

The use of this tool is based mainly on group discussion and brainstorming, the objective of which is to develop a list of the following items:

1. *Internal strengths:* resources or capabilities that help an agency accomplish its mission or implement an innovation (e.g., staff, adequate resources, leadership);
2. *Internal weaknesses:* deficiencies in resources and capabilities that hinder an agency's ability to accomplish its mission or to implement an innovation (e.g., lack of effective communication, lack of clear vision, lack of funding);
3. *External opportunities:* outside factors or situations that can affect an agency in a positive way (e.g., new federal funding, political support for a project, a chance to modify outdated procedures or mandates); and
4. *External threats:* outside factors or situations that can affect an agency in a negative way (e.g., loss of state funding, increasing demand for a specific service).

Each list should contain no more than 10 high-priority factors, with the factors' descriptions and the possible criteria or actions for coping with each factor.

EXAMPLE:

A state DOT is considering adopting a new management information system (MIS) for improving its operations. The following is a list of very preliminary considerations.

The opportunities for its implementation are

- Availability of new technology
- Newly appointed commissioner
- Possibility of commercialization
- Availability of federal grants

The potential threats that prompt implementation are

- Changing political climate and mandates
- Growing public dissatisfaction with service

Some of the organizational strengths that could help implementation are

- Availability of know-how
- Commissioner's support
- Highly motivated MIS unit

Some of the organizational weaknesses that could hinder implementation are

- Bureaucratic road blocks and delays
- Some units geared toward maintaining status quo
- Top staff turnover

TIPS:

- Consider what is going on outside the organization before considering what is going on inside.
- Review the SWOT lists to detect patterns and actions that might be taken immediately.
- Ensure accuracy and reasonable completeness by ensuring each list results from at least two or three iterations of brainstorming.

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- North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Toolbox.* Version 1.0. NCDOT, 1997.
- Bryson, J. M. *Strategic Planning for Public and Nonprofit Organizations.* Revised Edition. Jossey-Bass Publishers, San Francisco, 1995.
- Bryson, J. M. and F. K. Alston. *Creating and Implementing Your Strategic Plan.* Jossey-Bass Publishers, San Francisco, 1996.

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1. North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Toolbox.* Version 1.0. NCDOT, 1997.

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3. North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Toolbox.* Version 1.0. NCDOT, 1997.

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6. Bronitsky, L., and J. Misner. "A Comparison of Methods for Evaluating Urban Transportation Alternatives." *Urban Mass Transportation Association,* UMTA 7410–7411, No.75-5, 1975.

7. Jianling, L. "Electronic Toll Collection at Carquiñez Bridge." *Research Updates in Intelligent Transportation Systems,* Vol. 7, No. 3 (1998), pp. 1–11.

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9. *Transit Technology Evaluation: A Literature Capsule.* UMTA Report No. 81-65, Urban Mass Transportation Administration, 1981.

10. Jianling, L. "Electronic Toll Collection at Carquiñez Bridge." *Research Updates in Intelligent Transportation Systems,* Vol. 7, No. 3 (1998), pp. 1–11.

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PART III

EXAMPLES OF THE USE OF THE EVALUATION MODEL

OVERVIEW OF EXAMPLES

This section contains a set of case studies that show how the evaluation factors can be used for assessing a variety of innovations. The case studies refer to new equipment, materials, methods, and processes that have been adopted by Connecticut DOT, New Hampshire DOT, New York DOT, and Massachusetts Highway Department (MHD) a few years ago. The following are the innovations under consideration:

- Digital imaging technology, ConnDOT
- Ground-penetrating radar (GPR) for concrete cover study, NHDOT
- High-performance concrete (HPC) for bridges, NHDOT
- Light-emitting diode (LED) traffic signals, NYDOT
- Magic, anti-icing liquid, NYDOT
- Merritt Parkway guiderail (MPG), ConnDOT
- Partnering, MHD
- Superpave®, ConnDOT

In each case, evaluation issues are listed according to the order that is shown in Checklist C (see PART I), where they are grouped according to the following areas of concerns:

- Gathered documentation
- Preliminary assessment
- Characteristics of the innovation
- Effects of the innovation within the DOT
- Effects of the innovation outside the DOT
- Compatibility of the innovation with the DOT's resources
- Feasibility of implementation
- Implementation requirements

The cases do not address all the issues that are listed in Checklist C, because some of the issues were not applicable to the examined innovations.

Digital Imaging Technology, ConnDOT

Digital imaging technology is used for improving the collection of roadway data, which in the past required labor-intensive and time-consuming inspections. At ConnDOT, digital imaging boosts the performance of the existing integrated system of video images and data for storage and retrieval. The 1997 adoption of the technology was prompted by the use of two automatic road analysis (ARAN) systems to assess the conditions of more than 13 000 km of roadway. Road images are analyzed on-board by WiseCrax software and then edited on nonlinear editing stations. After conversion and editing, frames containing images and data are stored in 12-inch, double-sided laser disks that can be accessed by ConnDOT personnel at 44 retrieval stations throughout the state. The system computes the number of field trips saved and the time saved on field trips; these computations are used to analyze overall fleet vehicle use and fuel consumed. ConnDOT estimates that the state saves $1 million every year in such costs.

Gathered Documentation

Documentation gathered included

- Demonstrations and test results from various vendors of digital cameras and from storage device manufacturers.
- Data acquired from Delaware and Ohio DOTs.
- Search results from the Internet.
- Comparative market and technical analysis of digital technologies.

Preliminary Assessment

Benefits: Digital imaging technology provides savings in terms of hardware cost and personnel time for collecting and editing images and data. Digital images have better resolution than that of conventional videotapes and can be easily edited by using ad hoc software. Graphic data can be more easily linked to alphanumeric data. The use of a digital camera requires fewer stops on the road, improving safety for the operators.

Fit: The technology meets current needs for cost-effective and improved data and image collection procedures.

Feasibility: ConnDOT has been using imaging for its operations since 1971. The modular design approach of the image and data collection and retrieval system and advancements in computing, software, and electronic networking facilitate the integration of the technology into ConnDOT's procedures. In addition, the technology's capability meets existing mandates for data colection.

Desirability: Digital imaging technology offers a high performance-to-cost ratio when compared to other available alternatives. The overall improvement of the data collection and retrieval system benefits the work of several other ConnDOT units. This is the case of a multifunctional innovation that offers better quality at lower cost.

Characteristics of the Innovation

Radical/incremental change: The use of digital imaging and storage represents an incremental improvement in the way data are acquired and stored. The technology does not depart significantly from the current know-how of ConnDOT.

Divisibility: The shift from the existing to the new system can be phased.

Proprietary technology: The camera uses proprietary technology, but several other products with similar capabilities are available.

Demonstrations: Vendors can demonstrate the full process of digital imaging applications according to agency specifications. Continuous technical support is available.

Effects of the Innovation Within the DOT

Benefits: Digital imaging enhances the overall performance of current data collection and storage systems in terms of quality images and expanded use (when fully developed) by ConnDOT personnel. Reduced costs result from savings in film processing and purchasing costs, in time efforts for editing and transferring images to disks, and in the reduced storage space requirements that result from eliminating the use of film. The digital camera is much smaller and does not obstruct the vision of the person driving the van, as in the case of a film camera. In addition, the digital camera has much greater recording capabilities (up to three to four times longer), so the van must stop less frequently to change film. These factors make digital imaging and storage an attractive alternative.

Limitations: Rapid technological change could make this innovation obsolete. This concern is lessened by the expected short payback period of the investment.

Modified or new work procedures: The full integration of the digital imaging into the existing system requires significant changes in editing procedures, whose complete development is subject to a learning curve of 2 years.

Personnel jobs and motivation: The change in technology would result in long-term changes in the agency's needs for personnel, with a shift in job descriptions from civil to software engineers.

Effects of the Innovation Outside the DOT

Public image of the agency: The agency will be on the forefront in using state-of-the-art technology and will provide a cost-effective solution that could be imitated by other state DOTs.

Surrounding communities and industries: The availability of more accurate data and better images would ultimately result in better and safer roads. In addition, retrieval stations can be used for analyzing traffic accidents and resolving conflicting traffic information.

Compatibility of the Innovation with the DOT's Resources

Compatibility: Changes in work procedures are not a problem.

Funding: The negotiation for internal funding is facilitated by the previous success of imaging within ConnDOT.

Technical capabilities: The previous use of imaging technology makes ConnDOT's unit capable of meeting the challenge of implementing and refining the technology over the years. However, more specialized human resources are needed for realizing the system's full service potential to other ConnDOT units.

In-house feedback and improvement: An outreach program is planned for all possible users of the system.

Feasibility of Implementation

Cost-effectiveness: The incremental cost of the hardware and software are offset by savings in material, resource, and processing costs, and by the achievement of better results.

Departments affected: Implementation entails the involvement of personnel from the departments of Engineering; Research; Maintenance; Traffic; Right-of-Way; Planning, Inventory, and Data; and Permits.

Top management involvement: The Director of Research supports the adoption of digital imaging technology.

Legal concerns: As in the case of other electronic documents, digital imaging data can be manipulated.

Need for cooperation: Cooperation among various ConnDOT units is needed.

Coordination with other implementation activities: The implementation of digital imaging must be coordinated with ongoing pavement management research (e.g., stress analysis) without interrupting the usual support services.

Implementation Requirements

Demonstrations: Demonstrations by vendors are required for testing the effectiveness of the new technology.

Training: Because the unit's personnel have significant experience in imaging operations, training will be on-the-job.

Champion: The Director of Research is the main supporter.

Implementers: The research unit plays the key role; however, the effectiveness of implementation depends on the efforts of several ConnDOT units.

Communication: Continuous face-to-face communication is required for implementing digital imaging technology. Internal marketing, in addition, is useful for obtaining necessary funding.

Cost: The following expenses are expected: cameras ($7,000/each); hard disks ($1,000); retrofitting of vans ($400,000/each); tapes ($10,000); laser disks ($50,000); and two work-months for initial training and incorporation of technology.

Time: To ensure a seamless transition, the time of implementation is approximately 3 years (August 1997–May 2000); this includes evaluation, development, and field application.

Ground-Penetrating Radar (GPR) for Concrete Cover Study, NHDOT

By determining rebar location and concrete cover, ground-penetrating radar (GPR) facilitates bridge deck inspection activities for new construction. The technology is also used for condition assessment of existing structures. With GPR measurements, state DOTs can verify and pay contractors according to achieved results or can identify the most effective rehabilitation regime for existing decks. NHDOT developed and implemented GPR in 1999, in collaboration with FHWA and a local GPR supplier, Geophysical Survey Systems, Inc. (GSSI), as a part of an ongoing quality control/quality assurance (QC/QA) program.

Gathered Documentation

Documentation gathered included

- Test results from the use of the conventional, handheld magnetic devices (pachometers) that had been used prior to 1997.
- Data about the use of GPR in the area of geophysical surveys, bridge deck condition surveys, and pavement assessment.
- Documentation about other GPR applications (e.g., identification of underground tanks).

Preliminary Assessment

Benefits: GPR has higher accuracy and precision in measuring concrete cover and is a nondestructive measurement.

Compatibility: GPR meets current needs for improved and more reliable measurement procedures.

Feasibility: The technology can be integrated into the QC/QA procedures being utilized. Positive collaboration with and support by the supplier (GSSI) gives confidence to the agency.

Desirability: GPR replaces old technology. It is applicable to pavement management, maintenance, and construction projects and complements existing QA procedures. Modest initial expenditures lead to more accurate measures of conformance to construction specifications. NHDOT is willing to spend resources for a better product.

Characteristics of the Innovation

Radical/incremental change: A similar technology was used in other NHDOT past projects.

Divisibility: The adoption of GPR cannot be phased, but its development can be tailored to the agency's needs.

Adaptability: The innovation can be used to measure accuracy of rebar depths for bridge decks (new construction) as well as concrete and rebar deterioration measurement (rehabilitation).

Proprietary technology: The technology is proprietary.

Previous testing and validation: The use of GPR for other applications within NHDOT has shown reliable results.

Implementation package/support: The implementation package and continuous support are available from the supplier (GSSI).

Effects of the Innovation Within the DOT

Benefits: Faster, more accurate, and precise measurements help the agency to reward and to penalize contractors more efficiently. The adoption of GPR enhances the effectiveness of the QC/QA program by defining a realistic and achievable range of concrete cover tolerances.

Limitations: GPR is not user-friendly technology (dedicated software is needed for generating readable results). The cost-effectiveness of the technology strongly depends on its capability of ensuring precision and bias (repeatability and accuracy).

Modified or new work procedures: The implementation of GPR depends on the modification of existing measurement procedures and construction contract specifications.

Effects of the Innovation Outside the DOT

Public image of the agency: NHDOT will be in the forefront in using state-of-the-art technology.

Road users: There would be no direct effect on road users. Higher quality of concrete cover leads to fewer maintenance and rehabilitation interventions, thus improving service to road users and the local communities.

Risks from failure: If the GPR were to fail, inaccurate measurements would cause contractor's claims and loss of confidence in the agency's fairness.

Compatibility of the Innovation with the DOT's Resources

Compatibility: Implementation depends upon the concurrent training of personnel in using the technology and learning new measurement procedures.

Funding: Federal (FHWA) funding is available for development of new technology (or products). Regardless, NHDOT is willing to bear the expenses to achieve a better product.

Technical capabilities: The previous use of GPR technology (i.e., evaluation of deck conditions and pavement thickness) makes NHDOT capable of meeting the challenge of implementing and refining the technology over the years.

Outside providers: In order to expand its business, GSSI is eager to promote and to support the use of GPR. In any case, several suppliers of the same technology are available, although the cost to switch may be high.

Feasibility of Implementation

Cost-effectiveness: The modest cost of the hardware and software ($41,000) and NHDOT time efforts are more than balanced by the possibility of an FHWA grant for the antenna and by advantages that are offered by the increased efficiency in the construction and maintenance of bridge decks and further development of the QC/QA program.

Departments affected: Implementation entails the involvement of personnel from Materials and Research, Bridge Design (initially), and Construction (when new specifications have been developed).

Other stakeholders: The construction industry is the main party affected by this technology. The use of GPR during construction contract execution will change past methods of measuring performance.

Environmental concerns: The long-term effect of exposure to radar waves is not known.

Top management involvement: Top management support for the adoption of GPR is expected.

Need for cooperation: Cooperation between the supplier and NHDOT is needed for software customization and GPR development. New construction specifications and related compensation methods must be acceptable to contractors.

Coordination with other implementation activities: The use of GPR leads to new construction specifications whose development must be coordinated with other QC/QA activities.

Acceptability to governing bodies: The development project is sponsored by FHWA.

Risk during implementation: Processing and interpreting the data collected by GPR could be cumbersome and lengthy and could be wrongly interpreted. If GPR does not provide reliable results, other risks are involved with the failure of concrete cover.

Implementation Requirements

Tests: Field measurement tests are needed to determine GPR reliability and to develop measurement procedures.

Demonstrations: Demonstrations are required for familiarizing field personnel with the new measurement procedures.

Training and orientation: Because NHDOT is involved in the evaluation and development process of GPR, training of personnel can take place during this process. The supplier could also provide formal training.

Specifications: New supplementary conditions must be developed for incorporation in construction contracts.

Champion: The Materials and Research department is the champion, with the support of the supplier.

Implementers: Implementation depends on the efforts of Materials and Research (QA and measurement procedures), and on the cooperation of both Bridge Design and Construction for the development of the contractual specifications.

Key decision makers: Director of Materials and Research is the key decision maker.

Control/advisory committee: QC/QA committee (contractors, Construction, and Materials and Research) is the control/advisory committee.

Reports: Periodic reports to FHWA are required.

Communication: Continuous communication, control, and feedback between NHDOT and GSSI are required during the development of the product. Contractors must be educated and convinced about the reliability of the new measurement procedures.

Cost: NHDOT's time effort for product development, field tests, and development of specifications is the cost of implementation. The vendor contributes to development costs. (NHDOT received $50,000 grant from FHWA; $41,000 of this amount was spent on the purchase of hardware and software. The remaining amount was used for conventional, handheld pachometer and implementation.)

Time: Two years, including evaluation, development, and field application, is the time of implementation.

High-Performance Concrete (HPC) for Bridges, NHDOT

The innovation encompasses the use of high-performance concrete (HPC) in bridge (girders and decks) design and construction by NHDOT. One bridge was completed in 1996; a second bridge is currently under construction. HPC for bridges was a new product technology identified by the Strategic Highway Research Program (SHRP). NHDOT is one the of the six lead state agencies demonstrating the use of HPC for bridges. In 1994, focus teams (with the participation of industry, U.S.DOT, and universities) were formed to assist these states in their undertaking.

Gathered Documentation

Documentation gathered included

- Technical articles about the past successful use of high-strength concrete construction.
- Several SHRP publications about HPC.
- Data about the experience of Texas DOT with this material and test results by the University of Texas.
- FHWA and American Concrete Institute (ACI) definition of HPC performance (strength and durability) requirements.

Preliminary Assessment

Benefits: Benefits are increased strength and durability. The superior durability results in lower life-cycle costs. The use of HPC does not create any environmental hazard.

Fit: HPC meets NHDOT's mission and needs.

Feasibility: HPC can be integrated into NHDOT's existing design and construction procedures.

Desirability: Federal funds for demonstration projects and FHWA technical support are available. HPC can be used for other structural applications. Higher performance is achieved at a moderately higher cost of concrete work.

Characteristics of the Innovation

Radical/incremental change: HPC represents a radical change from NHDOT's technological tradition. Acquisition of know-how is required.

Divisibility: The innovation can be implemented through a phased approach.

Reliability of performance results: Data from previous experiences (Texas and Nebraska DOTs) are available, but results must be verified with local conditions.

Effects of the Innovation Within the DOT

Benefits: Increased concrete strength should lead to fewer girders and longer spans with overall construction savings. Long-term costs are reduced through greater durability, resulting in lower overall maintenance expenditures. Fewer maintenance interventions reduce the frequency of possible safety problems for inspection and maintenance personnel.

Limitations: The small size of the initial bridge project inhibits economies of scale for purchasing custom made precast components. Inexperienced fabricators may not achieve the required HPC strength (8,000 psi).

New specifications requirements: The implementation of HPC would benefit from the use of performance specifications. Although NHDOT currently uses prescriptive specifications, the agency is confident that the performance requirements of HPC can be met within the ongoing QA/QC program.

Effects of the Innovation Outside the DOT

Road users: Road users benefit from fewer potholes and cracks.

Surrounding communities: Fewer delays are expected because of the reduced number of maintenance interventions over the bridge life cycle.

Public image of the agency: Given the above-stated benefits, the public image of NHDOT is enhanced.

Long-term environmental impact: Environmental benefits are lower use of materials and decreased need for disposal of concrete waste from rehabilitation work.

Transferability to other agencies: Nine more states are expected to benefit from NHDOT experience.

Compatibility of the Innovation with the DOT's resources

Compatibility: The design and construction requirements of the HPC bridge are compatible with the existing NHDOT's procedures.

Funding: Federal funding is available for demonstration projects.

In-house technical capabilities: The design and construction requirements are within NHDOT's current technical capabilities.

In-house maintainability: After the successful implementation of the first demonstration projects, the technology can be incorporated into NHDOT's standard procedures.

In-house feedback and improvement: The phasing of demonstration projects allows for continuous improvement. Actual performance needs to be continuously monitored to improve design and construction specifications.

Outside providers: A number of qualified precasters guarantee continuous supply and open competition.

Feasibility of Implementation

Cost-effectiveness: The implementation of demonstration projects requires significant up-front engineering and construction planning efforts in learning and mastering the use of HPC.

Departments affected: The implementation entails the cooperation of Bridge Design, Construction, and Materials and Research.

Stakeholders: Stakeholders are the public, NHDOT, FHWA, and industry.

Level of newness to the agency: There is a need for information that correlates field condition severity and specified performance.

Top management involvement: Top management is committed to the adoption of HPC.

Management turnover: Job rotation ensures replacement in case of management turnover.

Need for coordination: Coordination is needed among the general contractor, fabricator, and ready-mix people.

Acceptability to local interest groups: Bridge construction creates concern for owners of the local businesses that abut the bridge—a problem for any new bridge construction project.

Implementation Requirements

Workshops: Financial support and clarification on content from focus team are needed.

Tests/demonstrations: Preconstruction tests are conducted by NHDOT and the University of New Hampshire (UNH). Phased approach is demonstrated through two bridge demonstration projects.

Champions: Champions are the focus team with Bridge Engineer and NHDOT-assigned Material Research personnel.

Key implementation personnel: In this case, the champions are also the implementers.

Key decision makers: At the technical and political levels, the commitment of the Commissioner, Chief Engineer, and Director of Project Development is required.

Training and orientation: There is need for personnel training.

Communication: There is need for continuous communication and coordination with contractors and fabricators. Materials, constructibility, and performance through the construction and life of the structure should be monitored to develop and to communicate more systematic knowledge.

Cost: Twenty-four work-months for planning and testing, outside research expenses (UNH) during preconstruction and operations, construction cost, and construction administration efforts are the costs of implementation.

Time: The time of implementation is 15 months for planning and 18 months for construction.

Light-Emitting Diode (LED) Traffic Signals, NYDOT

In this innovation, light-emitting diodes, popularly known as LED lights, replace the incandescent bulbs that have been conventionally used for traffic signals. The use of LED technology helps state DOTs to increase the reliability of traffic signals because LEDs are expected to have a longer life than incandescent bulbs. In collaboration with Signacon (a local supplier), NYDOT completed the installation of LED lights at more than 1,000 intersections during 1991–1999.

Gathered Documentation

Documentation gathered included

- Vendor evaluation and test results.
- Third-party certification that LED lights meet the luminosity and color intensity standards for traffic lights.
- Implementation efforts at NHDOT and MHD; however, the experience could not be used directly since the controllers employed by these states were different from those of NYDOT.

Preliminary Assessment

Benefits: Longer life, energy savings, and lower maintenance requirements offset the higher initial cost.

Fit: LED lights meet NYDOT's mission of providing safe transit to road users and of addressing the need for a reliable alternative to incandescent bulbs.

Feasibility: LED lights need a new controller. The feasibility of developing such a controller must be assessed.

Desirability: LED lights provide better performance at a lower operation cost and can be integrated into existing systems more easily than fiber optics and neon lights.

Characteristics of the Innovation

Radical/incremental change: LED is a new technology for NYDOT and requires changes in the agency's procedures. LEDs are installed differently from incandescent bulbs, since the proper orientation of the LED light source is critical. Personnel have to be trained and instructed in this regard.

Divisibility: The adoption can be piecemeal (one or more intersections at a time).

Previous testing and validation: Test results are available from the vendor. Also, results of third party evaluation show that LED meet current traffic standards.

Reliability of results: The results of NYDOT lab tests and demonstration projects could be used for final decision.

Effects of the Innovation Within the DOT

Benefits: Operation costs are reduced because of lower maintenance requirements. Fewer emergency calls for maintenance personnel can result in better planning of their other activities.

Limitations: There is a concern regarding the supply of LED lights, since there is only one local supplier. The initial cost of LED lights and the controller is higher, because if LED lights do not perform as promised, invested capital could be lost. NYDOT's inventory of LED lights must increase because of the lights' required orientation (left and right arrows are different for LED lights but are the same for incandescent bulbs). Concerns exist also about degradation of LED lights over time.

New specifications: New specification requirements have to be developed for installation and maintenance personnel.

Personnel: Existing personnel can be retrained for the work, so new personnel are not needed.

Effects of the Innovation Outside the DOT

Road users and surrounding communities: LED lights would provide increased safety for road users, since there would be fewer burnouts of signal lights. This would result in fewer flashing-light intersections, lowering the chances of collisions.

Long-term environmental impacts: Because LED lights consume less energy, they are environmentally friendly in the long run.

Compatibility of the Innovation with the DOT's Resources

Compatibility: The installation of LED is compatible with existing infrastructure and know-how. Only the retraining of personnel is needed. However, significant effort and know-how are required for developing the new controller. This objective can be met through subcontracting.

Funding: The required funds could be drawn from the regular operation budget.

Capabilities: The technical capability to install and maintain LED signals is available.

In-house feedback and improvement: A database would be maintained to monitor the performance and failure of LED lights. Changes can be made, based on the assessment of data.

Outside providers: Suppliers must be experienced in developing new controllers.

Feasibility of Implementation

Cost-effectiveness: Initial higher cost is justified by lower maintenance and energy cost and longer life.

Departments affected: Implementation entails the involvement of personnel from Operations, Purchasing, Office of General Services, and Office of the Controller.

Stakeholders: The public (road users), suppliers, and NYDOT are the stakeholders.

Level of newness to the agency: The product is new; however, the differences do not significantly affect NYDOT personnel's work procedures.

Need for cooperation: Cooperation is required among the supplier of the LED lights, the supplier of the controller, and NYDOT. Possible complaints by other suppliers (of incandescent lamps, neon lights, etc.) have to be addressed. Some data from Caltrans can be used for implementation since the controllers are similar to those used by NYDOT.

Risk from failure: The risk of LED failure is limited to the capital expenditure. The cost of switching back is relatively low.

Implementation Requirements

Lab tests: Luminosity and degradation tests have to be conducted at NYDOT labs.

Pilot projects: Implementation requires pilot projects to assess the effectiveness, feasibility, and reliability of the technology. Projects can be performed in phases (one approach light, all lights at an intersection, etc.).

Training and orientation: NYDOT personnel responsible for the installation and maintenance of traffic lights and controllers have to be instructed in the use of LED lights. However, this instruction is a small issue and could be done through memos.

Champions: The vendor and NYDOT traffic engineers are the champions of the use of LED lights.

Key implementers: The key implementers are the field engineers and regional personnel in Traffic and in Maintenance.

Communication: The unit failure database can be maintained to collect data regarding installation and failure of LED lights. These data could be used for directing necessary changes in the long run.

Cost: The cost of implementation would be approximately 1 work-year for testing and equipment changes. The lab tests would require additional time. Approximately 3 work-hours per intersection would be required for installation of LED lights and the controller.

Time: The implementation of the LED lights would be an ongoing process. Initial tests at two or three intersections were performed over a 3-yr period (1991–1994). NYDOT forecasted around 4,000 operational intersections by year 1999 (no data on this forecast was available at the time this report was written).

Magic, Anti-Icing Liquid, NYDOT

In 1994 and 1995, local municipalities in western New York State started experimenting with ICEBAN, a liquid deicing agent. At the time, NYDOT's role was just to reimburse the municipalities' expenses for the involved contractors. ICEBAN was used in conjunction with sand; however, NYDOT was trying to move away from sand-based deicers. NYDOT believed that sand did not solve the problem (formation of ice), but merely provided some amount of traction to skidding vehicles. Sand in isolation caused higher clean-up costs and environmental concerns. ICEBAN, when mixed with sand, gave better deicing results than sand alone; however, NYDOT did not find switching to ICEBAN very advantageous.

NYDOT was searching for new products that would not only help deicing but would also act as anti-icing agent (i.e., as inhibitors of ice formation on the roads). When Magic—a mixture of ICEBAN and MgCl—was first introduced to NYDOT in 1996–1997, the agency took a head start in experimenting with it. Magic was a liquid agent that could be applied ahead of snow storms and could therefore act as an anti-icer. It promised better melting power and also could be used as an enhancer for the salt stockpile. NYDOT consequently decided to experiment with Magic at 8–10 locations in 1997. By 1998, more than 40 sites were using Magic.

Gathered Documentation

Documentation gathered included

- Vendor evaluation and references.
- Feedback from Washington State and Minnesota DOTs.
- National committee meetings and reports.
- Feedback from municipalities and resident engineers.

Preliminary Assessment

Benefits: Benefits from Magic are improved safety level for road users and, since cleaning up of sand is not required, lower long-run costs. Magic can be applied before a storm instead of after (as is the case with sand, which can be blown away by traffic), resulting in improved safety and ridership, and less corrosion of bridges and decks. Magic is better for the environment than sand, because it does not affect water in watershed areas.

Fit: Magic meets NYDOT's mission of providing safe transit to road users and of being environmentally friendly.

Feasibility: Magic would be easy to implement since NYDOT has already used liquid anti-icing and deicing agents like CaCl. Specific equipment for Magic can be procured as existing equipment, which has an average life of 8–10 years, is replaced. The actual impacts on the environment need to be assessed. Until these impacts are evaluated, the implementation could be restricted by the Department of Environmental Conservation (DEC).

Desirability: Magic can be used as a deicing, anti-icing, and stockpile agent. It is better than other agents that can be used only for one or two of the above applications. In the long run, Magic would be a low-cost alternative and would provide better safety and workability than existing deicing agents.

Characteristics of the Innovation

Radical/incremental change: Magic is a new type of liquid deicing agent; however, it is not a radical departure from NYDOT's technical know-how since the agency has been using similar liquid agents in the past (CaCl).

Divisibility: Since NYDOT has the equipment and know-how to deal with liquid agents, the adoption can be phased over a period of time. However, if NYDOT had no familiarity with liquid deicers, large initial investments would be needed for equipment and personnel training.

Proprietary/patented technology: Part of the technology is patented (ICEBAN), which makes price a concern in the long run, although NYDOT has not experienced cost problems with past use of ICEBAN.

Previous testing and validation: Test results from the vendor are promising. Tests by other state DOTs have also shown good results.

Reliability of performance results: The available data are of a qualitative nature and have no quantitative basis. This can be a concern. The product, however, is undergoing evaluation by HITEC, and data would be available by the time Magic is fully adopted.

Implementation package and support: The vendor is ready to provide support and equipment for the initial parts of implementation and testing.

Effects of the Innovation Within the DOT

Benefits: The cost and effort to clean up the sand after the snow has melted would be eliminated. In addition, the collaboration between the ice control unit and the road weather forecast unit would help NYDOT to be proactive (i.e., to apply Magic ahead of storm and provide safe conditions to road users). This would boost the motivation of NYDOT personnel.

Limitations: Because it is a liquid, Magic could create slippery conditions on the road. If coordination with the weather forecast is not achieved, Magic is not used effectively.

New specification requirements: The evaluation of Magic requires comprehensive lab tests for effectiveness. The quality of Magic has to be closely monitored (especially because ICEBAN, a component of Magic, is a byproduct, and its quality cannot be closely controlled).

Strategic positioning of the agency: The use of Magic would be a part of ongoing effort on the part of NYDOT to keep the agency abreast with the latest technology in order to provide better services to road users. NYDOT realizes that if it is not able to provide a better service, someone else will (threat of privatization).

Effects of the Innovation Outside the DOT

Public image of the agency: Magic can be promoted as a proactive step to ensure the safety of road users, consequently enhancing NYDOT's public image.

Road users: Road users and commuters will benefit from safer roads and a lower number of accidents caused by skidding. In the long run, fewer traffic holdups caused by rehabilitation of corroded infrastructure are forecast.

Surrounding communities: Because the use of Magic decreases the corrosion of bridges and road decks, there will be fewer expenses for rehabilitation activities. Consequently, NYDOT's resources can be used for other types of services that benefit surrounding communities.

Long-term environmental impact: The impact of Magic on underground drinking water has to be evaluated. DEC has to approve the use of Magic, especially in watershed areas.

Compatibility of the Innovation with the DOT's Resources

Compatibility: Since the infrastructure and know-how are already available, implementation can proceed without much effort and without retraining of personnel.

Funding: The funds required for using Magic can be retrieved from the winter snow clearance budget.

In-house technical capabilities: The know-how and expertise are available within NYDOT.

In-house feedback and improvement: The quality of Magic should be closely monitored over time. An informal feedback system would be put in place to monitor the effect of Magic on safety.

Feasibility of Implementation

Cost-effectiveness: The use of Magic improves road safety conditions and reduces corrosion of roads and bridges. Even though the initial cost of Magic is higher, it would be cost-effective in the long run.

Departments affected: Maintenance, Weather Forecasting, Research and Materials, and Budgeting are the departments affected.

Stakeholders: The public (road users), municipalities, suppliers, DEC, legislature, NYDOT, and environmental agencies are the stakeholders.

Level of newness to the agency: Although the product is novel, NYDOT would benefit from the know-how of using other liquid agents in the past.

Environmental impacts: The impacts of Magic on water quality and roadside vegetation have to be evaluated.

Need for cooperation: To ensure continued use of the product, significant cooperation is required between the supplier of Magic and NYDOT.

Need for coordination with other activities: The coordination with the road weather forecast is crucial for the effective use of Magic.

Acceptability to regulatory agency: Acceptability by DEC during and after implementation is very important.

Risk from failure: If Magic fails, NYDOT may have to face the legislature. The effect of Magic on rubber is not yet clear.

Transferability to other agencies: If successful, Magic can be adopted by agencies within New York State and by other states.

Implementation Requirements

Workshops: Most of the workshops for promoting Magic will be arranged by the vendor.

Lab tests: Chemical composition and performance tests will be conducted at the vendor, NYDOT, and DEC labs.

Pilot projects: Eight to ten sites would be used to test the performance of Magic.

Training and orientation: NYDOT personnel responsible for snow clearance and control would have to be educated about the use and advantages of Magic. This need could be met through memos and vendor meetings.

Champion: The champion happens to be a field resident engineer who has been monitoring the use of Magic by municipalities.

Implementers: The implementers are the field engineers and people who work on site.

Key decision makers: The key technical decision makers—Project Manager, Division Director—have shown full support for the use of Magic.

Acceptability at political level: The acceptability of Magic at the political level is also crucial because of the involvement of other agencies, such as DEC. However, acceptability should not be a problem because of the environmental benefits associated with the use of Magic.

Control/feedback requirements: The implementation does not call for large-scale orientation and training efforts, workshops, or interaction with other NYDOT units. However, follow-up is required to ensure the effective use of Magic.

Cost: The time required is 1 hr per month for approximately 65 NYDOT personnel (60 employees at the 10 selected pilot sites and 5 at the main office).

Time: Two years are required to move from the testing phase to the full-scale adoption phase.

Merritt Parkway Guiderail (MPG), ConnDOT

The Connecticut Merritt Parkway was listed in the National Register of Historic Places in 1991 because of its parklike appearance, numerous ornamental bridges, decorative features, and historical significance (it was built in the 1930s). The parkway is considered an official state scenic route and is not accessible to commercial vehicles or trucks. These characteristics induced ConnDOT to develop a special master plan that governs all future construction work, including strict provisions for historical restoration of the parkway and safety and operational improvements. In this regard, a specific Merritt Parkway committee was established for developing the guidelines of the master plan. Composed of more than 40 members, the committee consists of a representative from each town abutting the parkway and ConnDOT personnel.

Part of the plan implementation process was the development of a guiderail system that resembles the parkway's original rustic timber railing and also meets the latest safety standards. The Merritt Parkway guiderail (MPG) system builds upon a previously developed FHWA guiderail system for national parks. The innovative feature of the guiderail system consists of a new design, namely the use of steel I-beam supporting posts. The original system was based on wooden posts that were deemed unacceptable because of the difficulty of replacing them in the event of major damage. The wooden posts were also inferior to steel posts in terms of construction and performance. The original system had been tested according to *NCHRP Report 230*, "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances" (*1*); this report was replaced in 1993 by *NCHRP Report 350*, "Recommended Procedures for the Safety Performance Evaluation of Highway Features" (*2*). Merritt Parkway's innovative guiderail system, currently under construction, meets the requirements of *NCHRP Report 350* and has been approved by FHWA for use on the nation's highways.

Gathered Documentation

Documentation gathered included

- Literature about historical preservation.
- Data about FHWA use of wood-backed timber guiderails in national parks.
- Reports about aesthetic barriers.
- Implementation guidelines of the Merritt Parkway master plan.

Preliminary Assessment

Benefits: The benefit of the guiderail system is that it is a traffic safety system whose aesthetic matches the historical and parklike appearance of the Merritt Parkway.

Fit: MPG meets the need of the local community and is consistent with ConnDOT's mission.

Feasibility: The guiderail must satisfy *NCHRP Report 350* requirements and meet master plan guidelines. MPG design builds upon application in national parks and can be integrated into ConnDOT's existing procedures for maintaining safety systems.

Desirability: MPG enhances relationships between ConnDOT and surrounding communities. Results are applicable to any similar historical parkway.

Characteristics of the Innovation

Incremental/radical change: The design of MPG is within ConnDOT's technology and know-how tradition.

Testing and pilots: Extensive testing and field evaluation are needed to verify design performance and to demonstrate technical advantages. Test results of the original system are available, but the tests were conducted according to superseded standards.

Effects of the Innovation Within the DOT

Benefits: The benefits of the MPG system are that it is a better product than the wood-backed timber system in terms of performance (*NCHRP Report 350* requirements are more stringent than those of *NCHRP Report 230*) and has easier construction (steel posts can be driven and are easier to work within frozen ground) and maintenance (steel posts are more durable than wood posts). A renewable resource (wood) is used for the rails. Wood may not need maintenance for small dents resulting from impact.

Limitations: Wooden material is more vulnerable to decay, cracking, and fire.

New specification requirements: New material and construction specifications are required.

Effects of the Innovation Outside the DOT

Public image of the agency: MPG enhances the social role of ConnDOT in the region.

Surrounding community: The MPG system improves the overall appearance of the parkway that services the local communities.

Compatibility of the Innovation with the DOT's Resources

Compatibility: The design, testing, and construction requirement of the MPG system are compatible with ConnDOT's existing procedures.

In-house technical resources: ConnDOT has the capability of completing design and testing, including new construction specifications.

Feedback and improvement: Stage 2 of in-service evaluation per *NCHRP Report 350* is planned. Safety (e.g., number and severity of accidents) and maintenance performance is to be monitored continuously. Possible delineation problems created by the varying color shades of wood are to be assessed.

Outside providers: Local contractors can complete construction according to ConnDOT guidelines.

Feasibility of Implementation

Cost-effectiveness: MPG is not as cost-effective as conventional steel guiderails. A cost premium is incurred for meeting aesthetic requirements. The overall cost of the system needs to be kept down.

Departments affected: Implementation requires the cooperation of personnel from Highway Design, Bridge Design, Construction (inspection), and Maintenance departments.

Stakeholders: Both public opinion and the opinions of the people located along the Merritt Parkway must be taken into consideration.

Top management involvement: The adoption of MPG is supported by top management.

Acceptability: Design must be negotiated with and approved by the members of the Merritt Parkway committee, whose interests and perceptions may not be homogeneous.

Risks: Possible safety problems can be detected during the tests per *NCHRP Report 350* guidelines. Possible constructibility problems and aesthetic issues (i.e., wood's variable color shades) should be considered.

Transferability to other agencies: The use of previous test results (National Park experience) is limited because new testing procedures are in place. Other states can benefit from the development of MPG.

Implementation Requirements

Field tests: Design must comply with the *NCHRP Report 350* provisions for Test Level 3 and with ConnDOT's deflection criterion and must facilitate the installation of mild curbing underneath MPG.

Training and orientation: There is need for training of maintenance personnel.

Pilot projects: The phased nature of constructing the system allows the verification of constructibility and availability of materials.

Champions: The Merritt Parkway committee and ConnDOT designers are the champions.

Implementers: ConnDOT's highway engineers are the implementers.

Stakeholders: The development of the MPG system is a potentially sensitive issue for abutting communities.

Control/feedback requirements: There is need for continuous communication during design and construction.

Publications: The results of crash tests were published in *Transportation Research Record 1599*, "Roadside Safety Features and Other General Design Issues" (*3*).

Cost: The cost of implementation is a 9-month effort for development (one full-time engineer), the cost of crash testing, and the cost of constructing the system.

Time: The time of implementation is 2 years for design, testing, and construction (part-time) and about 2 years for construction.

Partnering, Massachusetts Highway Department (MHD)

Partnering is an innovative way of conducting business in which the traditional adversarial relationship between two or more organizations collaborating on a project is changed to a team-based relationship. This goal is achieved through promoting open communication, trust, understanding, and teamwork among participants.

Partnering started at MHD in 1996 when the technique was promoted as a part of FHWA's National Quality Initiative (NQI) and adopted by MHD as a part of its own quality initiative, the Massachusetts Quality Initiative (MQI). MHD's main purpose in adopting partnering was to reduce the litigation costs for disputes between MHD and contractors and suppliers.

Gathered Documentation

Documentation gathered included

- Results of partnering at U.S. Army Corps of Engineers.
- Results of partnering at other state DOTs, such as TxDOT and Arizona DOT (AzDOT).
- Results of partnering at Central Artery/Tunnel Project in Massachusetts.
- Input from FHWA.

Preliminary Assessment

Benefits: Benefits are a reduction in litigation costs and time for dispute resolution; improved relationships with the contractors and suppliers; and a reduction in the growth of cost, schedule overrun, and number of change orders and their associated cost.

Fit: Partnering meets the MHD's mission by ensuring lower litigation costs and time and therefore enables MHD to concentrate more on its core business. Partnering is also a part of MQI, the QC/QA effort of the MHD. Fewer disputes with contractors and suppliers would result in better relations with them and, in turn, with the political forum and the public.

Feasibility: Partnering calls for a new way of interacting with people and for a change in people's attitudes. Changing the behavior of people in business transactions is a challenging task.

Desirability: There are indications that FHWA might mandate partnering as a part of its alternative dispute resolution (ADR) process for all future funded projects. Because of this possible mandate, there is an incentive for MHD to be proactive and experiment with partnering. It can work well in conjunction with other projects of MHD, such as MQI and QC/QA. The implementation potential and applications of partnering are unlimited, and it can be extended to any other project in which more than one party is involved. The cost associated with partnering is extremely small compared with the potential costs of litigation, making partnering worthwhile to try.

Characteristics of the Innovation

Radical/incremental change: The know-how required for executing partnering is not available within MHD and is a radical change from the existing work culture.

Divisibility: Partnering can be adopted in piecemeal fashion (MHD does not have to risk many resources to experiment with it). Some parts of partnering can be used independently and therefore can be used by other units within MHD in their operations.

Adaptability: Partnering can be used in many MHD operations. The parts of partnering that are applicable to a particular context can be used independently, making partnering highly adaptable.

Previous testing and validation: The results from the U.S. Army Corps of Engineers, TxDOT, AzDOT, and the Central Artery/Tunnel Project in Massachusetts show savings through reduction of litigation costs and time, as well as through reduction of change orders.

Effects of the Innovation Within the DOT

Benefits: Partnering promotes a better working environment in MHD. It improves communication and coordination among MHD and contractors and decreases the number of disputes. When applied to both design and construction, partnering produces more efficient results in terms of cost and time.

Limitations: MHD personnel may feel that partnering is compromising, giving in to the contractor, or being too lenient toward abutters and third parties, which could drive up costs. Contractors may view partnering as a loss of lucrative change orders. Staff turnover during the contract could reduce the effectiveness of partnering.

New specification requirements: New specifications have to be developed to include partnering in the requests for proposals and contract administration procedures.

Effects of the Innovation Outside the DOT

Benefits: Partnering would improve the image of MHD with the industry and FHWA. Taxpayers and road users would benefit because of better road quality, lower costs, and shorter construction times. The long-term effects would include improved relations with contractors and better efficiency of MHD as a whole.

Risk of failure: The risks associated with failure of partnering are minimal, since the cost is negligible as compared with a given project as a whole (0.5 percent maximum) and as compared with the possible litigation charges.

Compatibility of the Innovation with the DOT's Resources

Funding: In-house funding is available for the promotion of partnering.

Availability of technical expertise: Because skill gaps exist, personnel need training in issues such as negotiation and communication.

In-house capability to sustain innovation: Upon development of the proper human infrastructure, it would not be difficult for MHD to sustain partnering, which could be incorporated into routine operations.

In-house feedback and improvement: Focus groups can be established to monitor the progress of partnering programs and to give input for further improvements.

Outside providers: External facilitators are needed to facilitate partnering workshops.

Feasibility of Implementation

Cost-effectiveness: Partnering is a low-cost, proactive method to save large litigation costs.

Departments affected: Almost all the departments of MHD would be affected by partnering. These include Construction, Highway Operations (design, traffic, and maintenance), Geotechnical, Environmental, and Materials.

Stakeholders: The stakeholders for partnering would be all those already involved, and those who could be affected by or can affect a project. They are MHD, contractors, FHWA, environmental groups [e.g., Department of Environmental Protection (DEP) and EPA], utilities, municipalities, police, surrounding communities, and so forth.

Top management involvement: Support from top management is crucial for implementation and maintenance of partnering.

Management turnover: Management and personnel turnover could have a major effect on the success and effectiveness of partnering, because development of human resources for partnering takes considerable time and effort.

Need for cooperation: The key to successful partnering is cooperation between the suppliers or contractors and MHD.

Need for coordination with other activities of the DOT: Coordination with the QC/QA effort would enhance the effectiveness of both processes.

Acceptability to local interest groups: The acceptability to contractors and local communities is also very important.

Acceptability to regulatory and funding agencies: FHWA acceptance is required when FHWA funds the project.

Transferability to other agencies: MHD can benefit from the experience of other state DOTs. However, because of the different local conditions and work cultures, experiences from other state DOTs may not be fully applicable.

Implementation Requirements

Workshops: Workshops for partnering are required for contractors, suppliers, other public agencies, and MHD personnel. In a partnering process, all the parties of a project come together to communicate clearly and to reach a common understanding so that there are no later disputes. Every project, therefore, should have initial workshops and a number of follow-up meetings.

Training and orientation: Personnel need training to enhance their communication skills and their dispute resolution skills.

Pilot project: Several pilot projects are needed for successfully understanding and implementing partnering. These projects could be used as training vehicles.

Publications: Newsletters are useful tools for publishing the results of partnering.

Champion and implementers: A single champion (the Coordinator of Partnering), empowered by top management, will oversee the implementation of the program. However, district resident engineers will actually implement partnering, and their acceptance is very important.

Acceptability at political level: Support from high-level officials (e.g., the Commissioner) is also crucial for the success of partnering.

Acceptability to other stakeholders: Acceptability to suppliers and contractors is required to implement partnering.

Communication: The following are important communication media: orientation and training (MHD and suppliers), workshops (MHD top management and construction executives), face-to-face interaction, and reporting and accountability (to the Chief Engineer). Several meetings of senior personnel are required to promote partnering.

Cost: Approximately five full-time salaried personnel (one per district) are required to maintain and monitor partnering in Massachusetts. This number does not include the coordinator of the statewide partnering program. The cost of training, workshops, reports, and evaluation is additional. Time efforts for developing partnering are not considered a major cost, since they represent a very small fraction of a project as a whole.

Time: The full implementation of partnering will require approximately 10 years.

Superpave®, ConnDOT

Superpave employs an innovative way of designing hot-mix asphalt mixtures using project-specific conditions. The innovation was developed as a part of the State Highway Research Program (SHRP), which was established by Congress in 1987. Superpave research and technology was developed and tested over a period of 5 years and was ready for adoption by various state DOTs in 1992. ConnDOT was not one of the first state DOTs to adopt the technology. ConnDOT had been using conventional mix design for its pavements and was satisfied with the pavement's performance for most locations, except for the locations with heavy traffic. ConnDOT realized the potential of Superpave for use at these locations, decided to adopt it, and began training personnel in 1993 for Superpave design. By that time, FHWA had successfully experimented with Superpave and was looking for sites for pilot projects. ConnDOT received FHWA approval for a pilot project in 1996 and started construction in 1997.

Gathered Documentation

Documentation gathered included

- SHRP guidelines.
- AASHTO specifications.
- Results of coordinated experiments by FHWA, Pennsylvania State University, and Northeast Regional Center.
- Experience of other state DOTs.

Preliminary Assessment

Benefits: At a slightly higher cost, Superpave provides a more durable pavement with a smoother ride. Longer service life reduces the maintenance requirements of roads. The innovation supports emission recycling and control.

Fit: Superpave meets ConnDOT's mission by providing better roads for longer periods of time, improving service to road users. It supports existing QC/QA efforts and is consistent with the environmentally friendly strategy of ConnDOT.

Feasibility: The innovation is not a radical change in the way ConnDOT constructs and tests conventional pavements. Superpave is about 20 percent different from the current paving system and can therefore be integrated into existing procedures and practices without much difficulty. Hazardous fumes from the mix are similar to those in mixes previously used.

Desirability: Superpave is part of a federal program that provides bulk purchasing savings and training for ConnDOT personnel.

Characteristics of the Innovation

Radical/incremental change: Superpave represents an incremental change from ConnDOT's technological tradition. Some activities of the innovative process can be performed by using conventional equipment and existing expertise. Other activities require the acquisition of new know-how. Final specifications have to be developed.

Divisibility: ConnDOT can adopt the technology incrementally over a period of 3–5 years.

Adaptability: Superpave is adaptable to various types of roads and has the potential to be implemented on a statewide basis.

Proprietary/patented technology: Although the lab equipment is patented, FHWA has retained more than one supplier to ensure competitive prices.

Previous testing and validation: Superpave has been tested and approved by FHWA and other state DOTs. The initial research results and guidelines are available from SHRP. AASHTO specifications are available.

Results of pilot projects: Pilot projects cannot give immediate answers about the long-term performance of the innovation.

Transferability of other agencies' experience: New York, a lead state in the "AASHTO Implementation Assistance Program," can provide assistance in ConnDOT's effort to implement Superpave. ConnDOT would also be able to utilize the technical expertise from the Maryland State Highway Administration, which has been a successful early user of the innovation.

Effects of the Innovation Within the DOT

Benefits: The benefits of Superpave are an increase in the service life of asphalt (by 2 years according to FHWA estimates), fewer maintenance-related delays for road users, and less wear and tear on vehicles.

Limitations: The performance of Superpave is more sensitive to production variations than traditionally designed mixes. The Superpave process imposes restrictions on the flexibility of producers, who must invest in new equipment (e.g., gyratory compactor) and retooling.

New specification requirements: The adoption of Superpave requires development of new performance specifications. Contracting procedures must be changed to match the new requirements of Superpave.

Effects of the Innovation Outside the DOT

Benefits: A benefit of the innovation is better ridership, since Superpave results in fewer maintenance-related traffic delays. Also, better durability means fewer bumps and potholes, which equals a more comfortable drive.

Surrounding communities: The surrounding community is not an issue during implementation. Superpave causes the same amount of discomfort as the conventional system. Communities benefit in the long run.

Long-term environmental impacts: Superpave supports recycling [except reclaimed asphalt pavement (RAP)].

Risk of failure: If the program fails, industry retooling would be needed, with consequent loss of confidence.

Compatibility of the Innovation with the DOT's Resources

Compatibility with existing procedures: The incorporation of Superpave into ConnDOT's existing work procedures requires that suppliers will have to be trained and will have to retool their equipment.

Funding: Federally targeted funding is available for equipment, training, demos, and so forth.

Availability of technical capabilities: Training of personnel is required. Once the program progresses, incremental improvement can be obtained with continuous monitoring.

Outside providers: The technology will affect contractors who have not yet changed for other states; these contractors will have to adjust to meet the specifications.

Feasibility of Implementation

Cost-effectiveness: Expected benefits (longer service life and reduced delays) offset initial (equipment and training) and recurrent costs (equipment maintenance).

Departments affected: The implementation entails the cooperation of the following ConnDOT units: Traffic and Planning (data), Research and Materials, Maintenance and Construction, and Design Services.

Stakeholders: The public, ConnDOT, FHWA (for the pilot project), contractors, and suppliers are the stakeholders.

Top management involvement: Commitment by the Director of Research and Materials is necessary.

Management/personnel turnover: Few people will be trained in the new technology. ConnDOT cannot afford to lose them if additional personnel are not trained.

Need for cooperation: There is the need for cooperation among contractors, producers, and ConnDOT because of the changes in procedures and the equipment and training associated with the adoption of Superpave.

Coordination with other programs: The Superpave program must be coordinated with the QC/QA effort of the agency.

Acceptability to interest groups: The adoption of Superpave will be opposed by the concrete industry.

Implementation Requirements

Training and orientation: Six research and testing engineers will be trained in the use of Superpave. Additional training must be provided for the implementation of binder specifications and proficiency testing with industry. Also, orientation and training is needed for contractors.

Lab tests: New testing procedures must be developed and followed by a testing program.

Pilot project: A pilot project is required for testing implementation and developing guidelines and specifications for future applications.

Publications: In addition to new specifications, ConnDOT must develop a new statewide guide that assists in selecting the appropriate mixture for a given project.

Champion/key decision makers: The Director of Research and Materials is both the champion and key decision maker. Acceptability to higher-level officials (Chief Engineer, Commissioner) is required.

Implementers/key personnel: Research and Materials personnel are the implementers and the key personnel.

Communication: Orientation and training for ConnDOT personnel and contractors and workshops for ConnDOT management and contractors are necessary.

Cost: The cost of implementation is the training of 12 ConnDOT engineers, purchasing and maintaining equipment, retooling efforts, developing specifications and the final guide, and monitoring the performance of pilot projects. The cost of overlays is expected to increase by approximately 7 percent.

Time: Full implementation is expected to last about 10 years (1992–2002). It can be completed in 5 years, but ConnDOT has less incentive to accelerate the adoption of Superpave, since it is satisfied with the existing procedures.

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3. Lohrey, E. C., J. F. Carney III, D. L. Bullard Jr., D. C. Alberson, and W. L. Menges. "Testing and Evaluation of Merritt Parkway Guiderail" in *Transportation Research Record 1599.* Transportation Research Board, National Research Council, Washington, D.C., 1997, pp. 40–47.

PART IV

ANNOTATED BIBLIOGRAPHY

The entries in this bibliography are sources of information for state DOT officials to consult during innovation evaluation and implementation. Some references appear without annotation because they are cited in the text, and their contents are discussed therein.

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The paper presents a quantitative comparative approach to alternative technologies that is based on preset objectives of the decision maker and the merits of each considered technology. The approach involves the identification of risk factors associated with each technology, the setting of the criteria to be used in the analysis, the quantification of the factors with respect to criteria, and aggregating factors and the criteria to produce a final score for each alternative. The paper describes various evaluation techniques, such as multiattribute decision making (MADM), pair-wise comparison, and sensitivity analysis. It also discusses the following evaluation criteria: cost, time, competitive advantage, environmental factors, and risk factors.

Averch, H. A. "Criteria for Evaluating Research Projects and Portfolios." In *Evaluating R&D Impacts: Methods and Practice,* Kluwer Academic Publishers, Boston, 1993, pp. 263–278.

The paper describes some prototype strategies and criteria for evaluating the utility of individual research projects and portfolios of projects. It also discusses how to judge whether existing portfolios are the best that can be obtained. Peer review and portfolio analysis are illustrated. In describing the techniques, a number of evaluation criteria are outlined: cost, profitability, technical success, and market success. The paper describes the different evaluation methodologies used for basic research, research portfolio, and innovative research. Also described are the strategies for evaluating the above-listed criteria.

Bandt, J. D. "Research and Innovation: Evaluation Problems and Procedures at Different Levels." *International Journal of Technology Management,* Vol. 10, Nos. 4–6 (1995), pp. 365–377.

The article argues that the evaluation problems in the field of research and innovation are not exceptional, but are similar to those that are raised in all informational service activities. It stresses the fact that evaluations can be made at very different levels and that because of multidimensionality, most evaluations are only partial. The article discusses issues such as evaluation at different levels and the evaluation of technology, socioeconomic effects, the decision process, and research and innovation activities and processes.

Bikson, T. K., S. A. Law, M. Markovich, and B. T. Harder. *NCHRP Report 382: Facilitating the Implementation of Research Findings: A Summary Report.* Transportation Research Board, National Research Council, Washington, D.C., 1996.

The report contains the findings of a study that was performed to identify the factors affecting implementation of research results. It delineates strategies that are expected to promote innovation implementation and outlines further research to test the more viable strategies for putting transportation research results into practice. The report provides recommendations for state highway and transportation agencies and other highway organizations that pursue effective implementation of research results.

Brand, D. "Criteria and Methods for Evaluating Intelligent Transportation System Plans and Operational Tests." *Transportation Research Record 1453*, Transportation Research Board, National Research Council, Washington, D.C., 1994, pp. 1–15.

The paper describes the evaluation process for the planning of an intelligent transportation system (ITS) that is sensitive to the differences between ITS and conventional transportation improvements. A complete set of evaluation criteria and techniques for ITS improvement are presented. The techniques pertain to the evaluation of relative project merit by using pair-wise comparison, scoring, and cost-benefit analysis. The criteria include project time, operational efficiency, use control, safety, and implementation process.

Bronitsky, L., and J. Misner. "A Comparison of Methods for Evaluating Urban Transportation Alternatives." *Urban Mass Transportation Association,* UMTA 7410–7411, No.75–5, 1975.

The report investigates whether there is any formal, systematic evaluation procedure that is an improvement over unaided intuitive judgement based on impact data. The study investigates the use of various evaluation methods such as cost-benefit analysis, cost-effectiveness analysis (single/multiple measures), scoring methods, and judgmental evaluation. Feasibility, skill requirements, information reliability and credibility, distribution issues, political process, and ease of detecting biases are evaluation criteria that are used for critically analyzing the above-listed evaluation methods.

Bryson, J. M. *Strategic Planning for Public and Nonprofit Organizations.* Revised edition. Jossey-Bass Publishers, San Francisco, 1995.

The book promotes understanding of the concept of strategic planning and its application among the policy makers and managers of public and nonprofit organizations. The book contains a useful combination of theory and practice for students of strategic planning and outlines techniques such as SWOT analysis, snowcards, and oval structuring for problem modeling purposes.

Bryson, J. M., and F. K. Alston. *Creating and Implementing Your Strategic Plan.* Jossey-Bass Publishers, San Francisco, 1996.

The workbook addresses key issues in the design of an overall strategic planning process and subsequent implementation process. The workbook is divided into two sections: Part 1 presents a step-by-step overview of the strategic planning and implementation process and the benefits to be gained by using it; Part 2 covers each step of the process in more detail. Each step description includes sections on purpose and possible desired planning outcomes. Parts 1 and 2 contain worksheets to guide the user through and to facilitate the process.

Bryson, J. M., and A. L. Delbecq. "A Contingent Approach to Strategy and Tactics in Project Planning." *Journal of American Planning Association,* April 1979, pp. 167–178.

The article discusses how the project planning strategy and tactics of an experienced planner may change under varying circumstances to increase the likelihood of success.

Chang, L., D. E. Hancher, T. R. Napier, and R. G. Kapolnek. "Methods To Identify and Assess New Building Technology." *Journal of Construction Engineering and Management,* Vol. 114, No. 3 (September 1988), pp. 408–425.

The paper describes the development of a mechanism for seeking new technologies and introduces a framework for the assessment of technology's impact on the U.S. Army construction program. The paper discusses cost-benefit analysis and risk assessment as evaluation techniques. The framework incorporates a methodology for impact assessment.

Chee, M. Y., and W. E. Souder. "A Filter System for Technology Evaluation and Selection." *Technovation,* Vol. 13, No. 7 (November 1993), pp. 449–470.

The paper describes the development and application of an integrated model for technology selection. A two-stage technology selection process is presented. The first stage consists of an elimination filter; the second stage consists of the technology selection procedure. The article also illustrates filter criteria and methodologies. The considered filter criteria are solution to immediate problems, ease of implementation, degree of newness of technology, requirement for incremental knowledge, potential usefulness of technology, and addition to core competence. The various filter systems discussed include a linear programming model, characteristics of candidate technologies, interrelations, cultural and human aspects, and environmental factors.

Cheslow, M. D. "Issues in the Evaluation of Metropolitan Transportation Alternatives." *Transportation Research Record 751,* Transportation Research Board, National Research Council, Washington, D.C., 1980, pp. 1–8.

The paper is a part of a study by the Urban Institute for improving the cost-estimation methods and evaluation procedures of the Urban Mass Transport Association's alternative analysis process. Several important issues related to evaluating alternatives are discussed. They include problems and advantages of several analytical evaluation techniques, such as cost-benefit analysis, cost-effectiveness analysis, and scoring models. Other evaluation methods are included: reduced table of measures, tradeoff analysis, threshold analysis, pair-wise comparison, dominance analysis, and marginal analysis. "Consumer benefits" was the main criterion used for the evaluation of all the alternatives. The paper also illustrates methods of organizing and presenting information, reducing dimensionality of evaluation measures, and stages of evaluation and purpose.

Clemen, R. T. *Making Hard Decisions: An Introduction to Decision Analysis.* Duxbury Press, Belmont, CA, 1996.

The book is an overview of decision-analysis techniques. It covers the following evaluation techniques: decision trees, risk analysis/modeling, uncertainty modeling, sensitivity analysis, and multiattribute utility models.

Cooper, R. G. "An Empirically Derived New Product Project Selection Model." *IEEE Transactions on Engineering Management*, Vol. EM-28, No. 3 (August 1981), pp. 54–61.

The paper emphasizes the importance of the screening stage, or the R&D project selection decision phase. The screening stage is the initial go–no go decision of a new product project. It is the decision point at which management commits significant resources toward the development of a new product. The effectiveness of the screening decision is crucial to the success of R&D programs.

Cullison, J. T., and G. L. Gittings. "Development of Project Priority-Setting Methodology for Pennsylvania's Airport Development Program." *Transportation Research Record 1562,* Transportation Research Board, National Research Council, Washington, D.C., 1996, pp. 19–27.

The paper describes how the critical problem of the seemingly endless list of infrastructure needs and limited resources for transportation improvements is addressed in Pennsylvania. A decision making tool for choosing among candidate projects of a state airport development program is presented. The paper illustrates the evaluation techniques of group discussion and scoring and the following evaluation criteria: airport activity, project factors, sponsor compliance, distribution of funds, federal aid, and funding issues. The methodology for project selection, guiding principles for group discussions, and priority system framework are also described.

Danila, N. "Strategic Evaluation and Selection of R&D Projects." *R&D Management,* Vol. 19, 1989, pp. 47–62.

The most important families of R&D project evaluation and selection methodologies and associated techniques are briefly reviewed in the article. Some definitions and aspects of the new strategic role of the evaluation and selection of R&D projects are presented. The strong and weak points of the prevailing methods are described. The evaluation-method families discussed in the article were the following: ratio, score index, programming, portfolio, matrices, systemic, relevance, table, multicriteria, consensus, graphic, and integrative. Evaluation procedures are outlined in the form of flowcharts.

Divine, D. R. "Overcoming Communication Barriers to Effective Technology Transfer." *Transportation Research Record 1565,* Transportation Research Board, National Research Council, Washington, D.C., 1996, pp. 1–3.

FHWA's Local Technical Assistance Program (LTAP) presents several examples of barriers that must be overcome to ensure effective technology transfer. The LTAP techniques discussed in the article demonstrate that effective technology transfer can occur with simple measures that do not require large expenditures or elaborate presentations. The article discusses barriers to communication, information collection and sources, environmental and other aspects, and elements for successful technology transfer.

Faulkner, T. W. "Applying 'Options Thinking' to R&D Valuation." *Research Technology Management*, Vol. 39, No. 3 (May–June 1996), pp. 50–59.

The article presents "options thinking" as a practical way to apply lessons from options pricing theory to some of the central problems of R&D management. It demonstrates that in some situations options pricing theory provides a better basis for the valuation of R&D projects than the traditional discounted cash-flow techniques used in most cases. The article also demonstrates the methodology of options thinking and calculation, the Japanese approach, and the implications and misuses of options thinking.

Federal Highway Administration. "Exploring the Applications of Benefit/Cost Methodologies to Transportation Infrastructure Decision Making." *Searching for Solutions,* FHWA-PL-96-014, No. 16, July 1996.

Ferguson, E. T. "Overview of Evaluation Methods with Applications to Transportation Demand Management." *Transportation Research Record 1321,* Transportation Research Board, National Research Council, Washington, D.C., 1991, pp. 146–153.

Transportation demand management (TDM) is becoming increasingly popular as a response to traffic congestion, air pollution, and related problems. The article discusses the importance of carefully evaluating previous successful projects and analyzing the various evaluation methodologies. The criteria that are used to evaluate TDM are customer benefits, environmental issues, resource utilization, and economic benefits. The described evaluation methodologies are the direct observation method, revealed preference method, stated preference method, organization sampling method, focus groups, and modeling TDM effectiveness.

Gaynor, G. H. "Selecting Projects." *Research Technology Management,* July–August 1990, pp. 43–45.

The article discusses the importance of understanding nonquantifiable issues for assessing the success of a project. It illustrates the questions to be asked when preparing a project for management approval and also provides guidelines for modeling effectiveness.

Griffin, L. I., III. "Engineers' Guide to Program and Product Evaluation." *FHWA Final Report,* FHWA-SA-93-028, Federal Highway Administration, 1990.

The first part of the report describes the functions and characteristics of FHWA's R&D efforts and the categories of R&D program and product evaluation. The second part describes the six-step procedure for conducting evaluations. The report discusses the following evaluation techniques: experimental designs, quasi-experimental designs, statistical inference, and hypotheses testing. The following criteria for evaluation of programs and products are considered: safety, customer benefits, and ease of operation and maintenance. The report also discusses the concepts of formative and summative evaluation methodology, process evaluation, effectiveness evaluation, retrospective, and prospective evaluations.

Hall, R. W. "Cost Effectiveness of Automated Highway Systems: A Case Study in Engineering Economic Analysis of a New Technology." *The Engineering Economist,* Vol. 41, No. 4 (Summer 1996), pp. 317–343.

The paper presents the framework for evaluating alternative automated highway systems (AHS) deployment concepts, with respect to life-cycle costs and cost-effectiveness. It provides a methodology that can be customized, as technologies are refined. The paper presents a case study of the application of engineering economy methods to the development of complex new technologies. The paper discusses cost analysis, cost-effectiveness, and cost-benefit analysis as the main evaluation techniques for comparing alternative projects.

Innovative Technology Evaluation Center. "Technical Protocol." Civil Engineering Research Foundation, no date.

Jayawardana, J., and D. J. Webre Jr. "Louisiana Port Priority Program: An Application of Benefit-Cost Analysis to Project Appraisal." *Transportation Research Record 1511*, Transportation Research Board, National Research Council, Washington, D.C., 1995, pp. 26–33.

The paper describes Louisiana's port construction development priority program and the methodology for evaluating capital investments. The methodology takes into account social, economic, environmental, and other effects from the state's point of view. The evaluation techniques discussed are benefit-cost analysis and project priority criteria. The considered evaluation criteria are completeness, project need, location, profitability, benefit-cost ratio, technical feasibility, economic feasibility, environmental impacts, and the management of portfolios.

Jianling, L. "Electronic Toll Collection at Carquiñez Bridge." *Research Updates in Intelligent Transportation Systems*, Vol. 7, No. 3 (1998), pp. 1–11.

Lohrey, E. C., J. F. Carney III, D. L. Bullard Jr., D. C. Alberson, and W. L. Menges. "Testing and Evaluation of Merritt Parkway Guiderail," *Transportation Research Record 1599*. Transportation Research Board, National Research Council, Washington, D.C., 1997, pp. 40–47.

Menke, M. M. "Improving R&D Decisions and Execution." *Research Technology Management*, Vol. 37, No. 5 (September–October 1994), pp. 25–32.

The article argues that decision and execution quality in R&D are very different, but that both can be improved by using a common set of tools. These tools include strategy tables, influence diagrams, sensitivity analysis, decision trees, and expected monetary value. The other topics discussed are R&D profile grid, R&D productivity curve, portfolio segment return analysis, and new product revenue forecast.

Menke, M. M. "Managing R&D for Competitive Advantage." *Research Technology Management,* November–December 1997, pp. 40–42.

The paper discusses the 10 best practices for R&D-related decision making derived from the successful experience of 10 organizations that have mastered these practices, as found in a benchmarking study conducted in 1979. The considered evaluation techniques are portfolio analysis and cost-effectiveness analysis. The paper also describes the practices for R&D decision quality and for evaluating projects quantitatively.

Merrifield, D. B. *Evaluating R&D and New Product Development Ventures: An Overview of Assessment Methods.* Center for the Utilization of Federal Technology, National Transportation Information Services, U.S. Department of Commerce, 1986.

The report presents the various assessment methods that are used for evaluating R&D and new product ventures. It describes the following evaluation techniques: checklists, scoring models, profitability measures, sensitivity analysis, risk analysis, decision analysis, and cost-benefit analysis. In addition, the report discusses the criteria that are used to evaluate alternatives, such as resource compatibility, project novelty, nature of the market, nature of the project, compatibility with current business, probability of technical success, market competitiveness and growth potential, newness of the product, development time, and profitability. The paper also discusses the value of information collection, stages of innovation process, and constraint analysis.

Michie, J. D. *NCHRP Report 230: Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances.* Transportation Research Board, National Research Council, Washington, D.C., 1981.

National Cooperative Highway Research Program. *NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features.* Transportation Research Board, National Research Council, Washington, D.C., 1993.

North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Guide.* NCDOT, 1997.

The guide provides a 10-step process that can be used by teams or individuals to improve work processes within a DOT department. The improvement steps are review mission and vision, choose a process, identify valid customer requirements, measure the process, identify improvement opportunities, implement obvious improvements, reengineer the process, solve the problem, plan ongoing monitoring, document results, evaluate the effort, and choose a new process.

North Carolina Department of Transportation, Productivity Management Section. *Continuous Process Improvement Toolbox.* Version 1.0. NCDOT, 1997.

The toolbox provides many of the necessary analysis and organizational tools that are used to implement the systematic improvement process outlined in the *Continuous Process Improvement Guide.* The tools include action plans, affinity diagrams, bar charts, benchmarking, brainstorming, cause-and-effect diagrams, checklists, check sheets, consensus building, control charts, cost-benefit analysis, criteria rating forms, decision matrices, flow charts, force field analysis, Gantt charts, histograms, interviews, line charts, management presentation checklists, multivoting, nominal group technique, Pareto charts, pie chart, root cause analysis, run-trend charts, sampling, scatter diagrams, surveys, SWOT analysis, value-added analysis, and weighted voting.

Organisation for Economic Co-operation and Development. *Integrated Strategies for Safety and Environment.* Road Transport Research Programme, 1997.

The report focuses on how evaluation methods and planning tools can be designed and used to give equal and coordinated consideration to the safety and environmental effects on road transport. The report is based on an international survey of OECD member countries. The report illustrates the following evaluation techniques: cost-benefit analysis, multicriteria analysis, and a combination of both; matrices; interaction diagrams; and checklists. The report also lists the criteria used for evaluation as they relate to road and traffic (7 indicators), safety and risk (6 indicators), environmental impact (11 indicators), instruments (2 indicators), and process (3 indicators). In addition, evaluation and decision processes are briefly discussed.

Organisation for Economic Co-operation and Development. "Policy Evaluation in Innovation and Technology: Towards Best Practices." *OECD Proceedings,* 1997.

The proceedings contain articles dealing with techniques and methodologies for evaluating innovation and new technology. The techniques discussed are peer review, matrix approach, systemic approach, financial methods, and technology forecasting. The proceedings also discuss the methodology for evaluating external and technical tasks of R&D (i.e., capability study, agile evaluation, steps in evaluation design, and integrated assessment matrix).

Reinke, D., and D. Curry. "Quantitative Methods for Evaluation and Selection of TSM Project Alternatives." *Transportation Research Record 912,* Transportation Research Board, National Research Council, Washington, D.C., 1983, pp. 42–46.

The paper discusses the importance of the cost-benefit ratio in performing the financial evaluation of the project. It also examines the limitations of cost-benefit analysis as a single evaluation tool and discusses cost-effectiveness analysis as an alternative technique. The paper mentions the following criteria for project evaluation: mobility, safety, social and environmental factors, existing facility, cost, benefit-cost ratio, number of users, program characteristics, performance measures, added capacity, consumer benefits, improved level of service, and future contingencies.

Roessner, D. "Use of Quantitative Methods To Support Research Decisions in Business and Government." *Evaluating R&D Impacts: Methods and Practice.* Kluwer Academic Publishers, Boston, 1993, pp. 179–205.

The article describes several evaluation techniques, such as benefit-cost ratio, profitability measures, and peer review.

Roussel, P. A., K. N. Saad, and T. J. Erickson. *Third Generation R&D.* Harvard Business School Press, Boston, 1991.

The book targets business leaders and managers by providing concepts that help them to manage R&D as a strategic competitive weapon. It describes the following evaluation techniques: risk modeling, uncertainty modeling, cost analysis, scoring, cost-benefit analysis, and portfolio analysis. The criteria for project evaluation include project attractiveness, uncertainty, and exposure to risk. The book also discusses the framework for R&D management.

Ryden, T. K., M. Morris, and P. Roussere. "Transit Information System and Evaluation Capability To Support Subarea Transportation Planning and Implementation." *Transportation Research Record 815,* Transportation Research Board, National Research Council, Washington, D.C., 1981, pp. 18–24.

Through a case study, the paper describes the use of information systems. The following evaluation criteria are illustrated: supply and service, utilization and service productivity, environmental and safety effects, and financial effects. The paper also examines the diagnostic process and the multimodal planning system for implementation.

Schoenbern, T. F., and J. M. Fredette. "So You Want To Set Up a Technology Evaluation Program?" *Technology Evaluation Workbook,* Federal Laboratory Consortium and U.S. Regional Technology Transfer Centers, 1997.

Souder, W. E. *Managing New Product Innovation.* Lexington Books, MA, 1987.

The book discusses types of innovation and argues that an innovation can be of an absolute novel type or it can be of a relative type (i.e., incremental change or technology transfer). The book illustrates the scope and importance of each management step in the project life cycle of an innovation until its implementation. The factors that are crucial for the successful implementation of an innovation are also discussed. Different technology transfer methodologies are classified, and guidelines as to when one method is preferred over another are provided.

Souder, W. E., A. Nashar, and V. Padmanabhan. "A Guide to the Best Technology Transfer Practices." *Journal of Technology Transfer,* Winter–Spring 1990, pp. 5–16.

The article summarizes the analysis of best technology transfer practices of a broad cross-section of government agencies, research institutions, and industrial laboratories. The research argues that different technology transfer practices should be used at the prospecting, developing, trial, and adoption stages of technology transfer.

Tavakoli, A., and C. S. Collyard. "Benefit-Cost Analysis of Transportation Research Projects." *FHWA Final Report,* FHWA/OH-92/003, Federal Highway Administration, 1992.

The research report addresses the issue of evaluation of completed research projects and develops an evaluation methodology, a system and computer application program based on benefit-cost analysis, a cost-effectiveness ratio, and a multiobjective technique. The report presents evaluation criteria that include cost, benefits, environmental factors, utilization of resources, and risk considerations. It also discusses a prototype evaluation model.

Transit Technology Evaluation. A Literature Capsule. UMTA Report No. 81-65, Urban Mass Transportation Administration, 1981.

The report describes a transit technology evaluation program that investigates the social, technical, and economic factors involved in the planning and operation of promising new transit technologies through studies in four basic areas: assessment, cost analysis, market research, and impacts investigation. The study includes the following evaluation criteria: cost, acceptability of overhead structures, availability of funding, technical risk, public and political support, and environmental issues.

Uppal, K. B., and H. Van Gool. "R&D Phase-Capital Cost Estimating." *Transactions of the American Association of Cost Engineers,* AACE, Vol.1 (1992), p. A.4.1.

The paper illustrates the following evaluation methods: cost analysis, gross approximation method, scoping type estimating, and statistical methods for project cost estimating.

Werner, B. M. "Measuring R&D Performance—State of the Art." *Research Technology Management,* Vol. 40, No. 2 (March–April 1997), pp. 34–42.

The paper discusses an integrated methodology that combines several types of quantitative and qualitative measures of evaluation, such as quantitative objective metrics, quantitative subjective metrics, qualitative metrics, and integrated metrics.

Williams, D. *TAC Synthesis of Practice Series No. 4. Performance Evaluation Mechanisms for Transportation Research Programs.* Transportation Association of Canada, 1996.

The report presents a synthesis of evaluation practices used by organizations conducting transportation-related R&D and information on how to evaluate the effects of transportation-related R&D. It also discusses the following evaluation techniques: expert opinion, client user opinion, cost-benefit analysis, case studies, and performance indicators.

APPENDIX

EVALUATION PRACTICES BY SELECTED STATE DOTs

This appendix contains documentation of the evaluation and implementation practices by five state DOTs. The documentation focuses on the following areas of interest:

- Discussion points for the evaluation and implementation of research results (Minnesota DOT)
- Selection criteria (New Jersey DOT)
- Evaluation and process improvement protocols (New Jersey DOT and North Carolina DOT)
- Tools for implementing research results (Utah DOT)
- Evaluation forms (North Carolina DOT)

DISCUSSION POINTS FOR IMPLEMENTING RESEARCH RESULTS (MINNESOTA DOT)

The following document from MNDOT suggests implementation discussion points about the following areas of concern:

1. Evaluation of research results,
2. Organizational issues,
3. Information products,
4. Product development,
5. Product demonstration, and
6. Evaluation of implementation results.

IMPLEMENTATION DISCUSSION POINTS

1. EVALUATION OF RESEARCH RESULTS

The value of research results needs to be considered before deciding to implement:

A) Did the research involve the people it was intended to benefit? If so, please identify the group or individuals.

B) Do the research results solve the problem identified in the initial problem statement for this research project? If not, why? What other problem(s) do the results solve?

C) Do the findings offer improvement over currently used products, processes or materials? Explain.

D) Are the results practical for application? If no, are there steps that can be taken to develop practical products based on the results? If yes, consider the items in Sections 2 through 6.

E) If the results of this research project indicate the need for further research consider the following:

Have the details for further research been outlined? If yes, where? Or attach a copy.

What is the probability that further research will occur? (Is a work plan being developed? Has funding been obtained? Are there other agencies that would be interested? Is there a need for follow-up at some point in the future?) In other words, what is our plan?

If additional research has been funded, give details: by whom/$ amount/date to begin and be completed.

2. ORGANIZATIONAL ISSUES

The key people, funding sources, and even culture of the organization where the results are to be applied need to be considered:

A) Who will benefit from this implementation? And are the people that would benefit from implementation supportive of this effort? If not, what will it take to convince them that these benefits can be realized?

B) Who will pay for the direct implementation costs? What's in it for them?

C) Will the implementation result in indirect costs? If so, *who will pay* for these?

D) What is the strategy to deal with any resistance to change on the part of end-users or people affected by implementation? Describe how the human element is considered in this strategy.

E) What are the major obstacles to implementation?

F) What tasks will be most effective in insuring implementation?

G) Are the research results perceived to be objective and timely? Explain.

3. INFORMATION PRODUCTS

If the completion of this research project necessitates the dissemination of information or training in order to make others aware of the results, please consider these items:

A) In easy to understand terms summarize the key findings of this research.

B) What groups or individuals need to receive information about the research results so it can be applied to solving real-world problems? What other organizations may have an interest in the results?

C) Specifically, what information do these groups or individuals need to know?

D) How can this information be communicated most effectively?

E) When should the information be disseminated?

F) Who is responsible for disseminating the information?

G) What will the cost be, and who will bear the cost, to disseminate the information?

H) Are photographs (or other media) available? If not, is there something to photograph now?

4. PRODUCT DEVELOPMENT

If a product other than information (for example: software, hardware, specification, standard, procedure, equipment, or tool) needs to be developed as part of implementation, consider some of these questions:

A) Describe the key features, advantages, and benefits of any product resulting from this research.

B) What product(s), besides information about research results, needs to be developed in order to solve real world problems?

C) Who (person, committee, organization) has to review/approve this product for use?

D) What group or individuals will use this product?

E) What are the steps to get this product developed and/or approved? How might the private sector be involved?

F) What is the schedule for these steps?

G) Who will be responsible for getting this product developed and/or approved?

H) What are the estimated costs to develop, approve, and apply this product?

I) How will any patent or copyright issues be resolved?

5. PRODUCT DEMONSTRATION

If a demonstration or operational test of a new product (or process) would be useful in supporting implementation, then consider the following:

A) Describe in detail the demonstration and how it would support implementation.

B) Who would coordinate this demonstration?

C) Who should attend this demonstration?

D) Where/when should the demonstration(s) be scheduled?

E) What costs are associated with the demonstration and how will they be paid?

6. EVALUATION OF IMPLEMENTATION RESULTS

The value of implementation results needs to be considered:

A) What are some potential positive outcomes of implementing the research results? For example: reduced costs, greater efficiency, environment effects or safety. How will these outcomes be realized?

B) In real and measurable terms, what are the costs and benefits of using these findings to solve this problem?

C) What is the level of risk associated with realizing the benefits?

D) How will the implementation be evaluated after the adoption of a new product, process or material?

E) Who will be responsible for measuring the results of implementation?

F) When/where will measurements take place?

G) What costs are associated with taking the measurements and how will they be paid?

Comments or questions may be directed to:
Mn/DOT Office of Research Administration
St. Paul, Minnesota 55155 MS 330
or phone (612) 282-2272
FAX (612) 296-6599

SELECTION CRITERIA (NEW JERSEY DOT)

The following checklist is from "Research Peer Exchange, October 1998, Information Package," by the Division of Research and Technology, NJDOT. The report illustrates the various steps of the research management process at NJDOT. The checklist contains some of the selection criteria of research projects.

Selection Criteria:

A proposal will demonstrate some or all of the following:

Musts:

1. Is cost effective and has realistic, well defined decision points and time line.

2. Supports the advancement of the Department's Strategic Transportation Agenda.

3. Satisfies the needs of the customer(s) and will likely be readily integrated into current practice and/or products.

4. Meets top management needs/external customer mandated directive.

Wants:

1. Brings new concepts and applications to the Department's mission.

2. Offers an opportunity for cost or time/efficiency savings or other performance improvement.

3. Exploits research conducted elsewhere or earlier to deliver value-added improvements through technology transfer or application to the New Jersey's problem conditions.

4. Contributes to a well balanced annual program by addressing diverse Departmental needs for research support.

EVALUATION PROTOCOL (NEW JERSEY DOT)

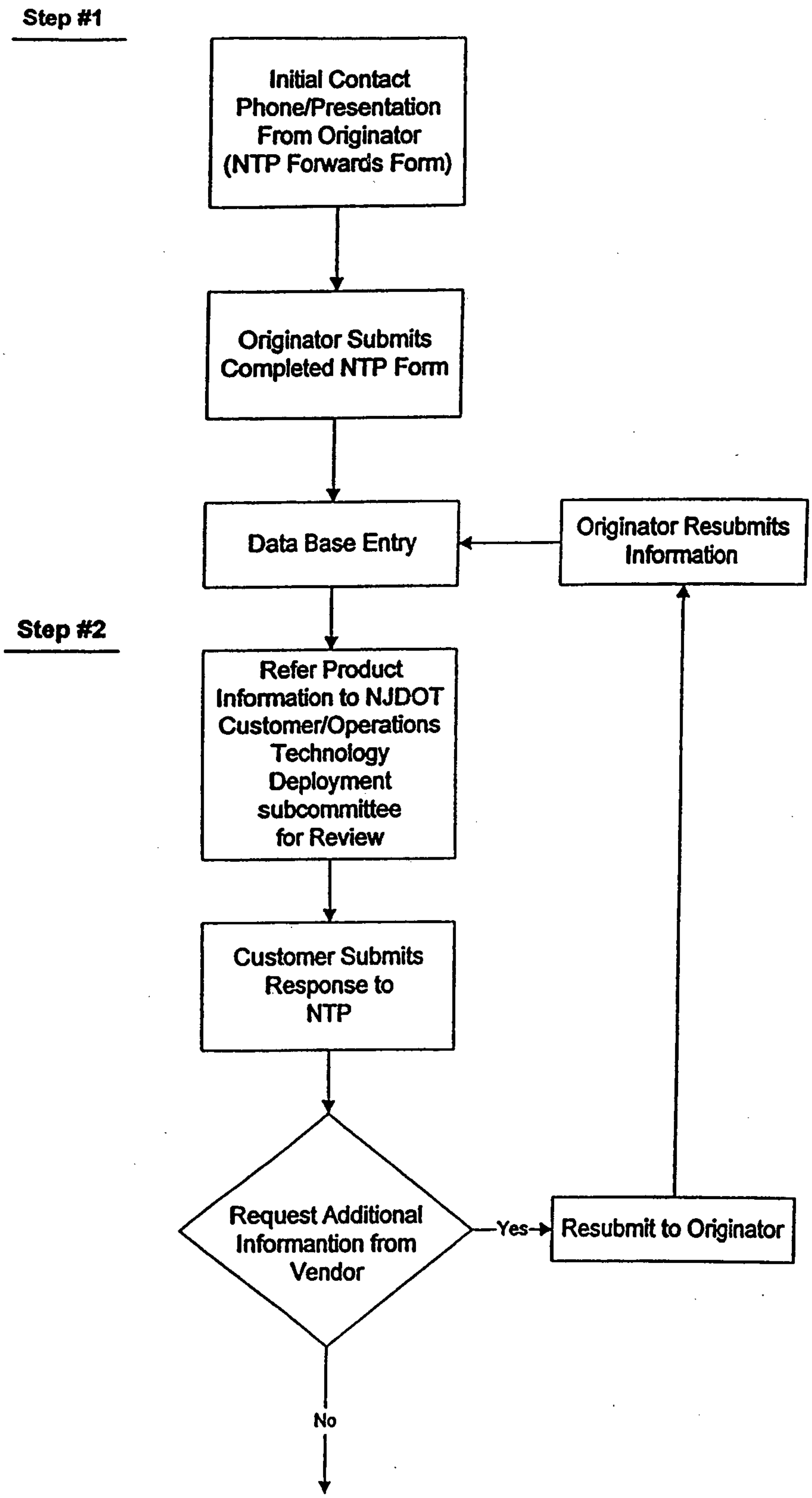
The following flowchart is from "New Technologies and Products (NTP)," *Annual Progress Report*, by the Division of Research and Technology, NJDOT, April 1998.

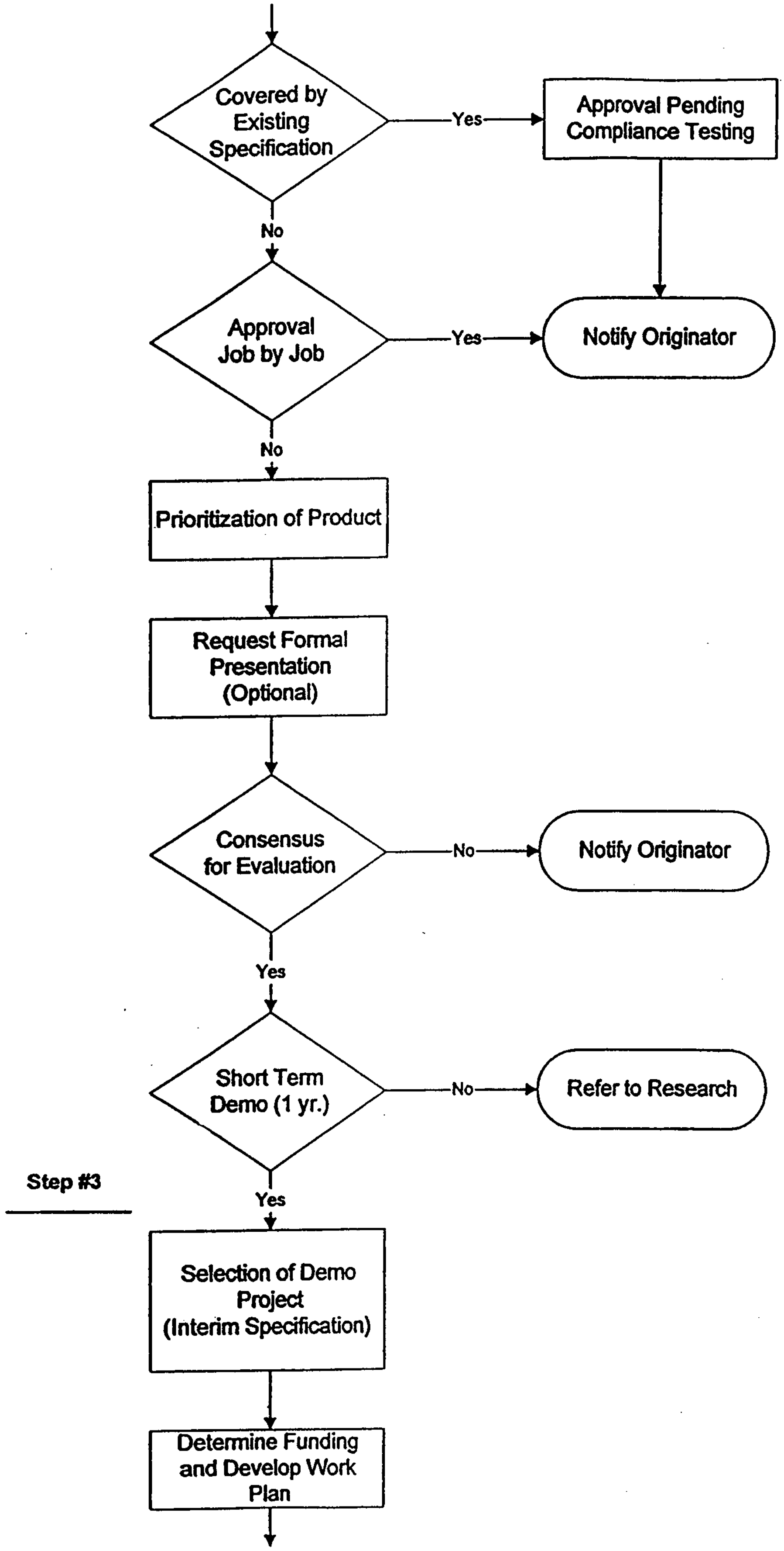
Within the NJDOT, the NTP program is responsible for identifying, reviewing, evaluating, and rapidly deploying new technologies, products, and innovations. The report documents the new technologies and product evaluation process and procedures and records the present new technologies and products database items that are approved for use, not approved, under review, or being demonstrated in experimental projects. The systematic evaluation of new technologies and products builds upon the following steps:

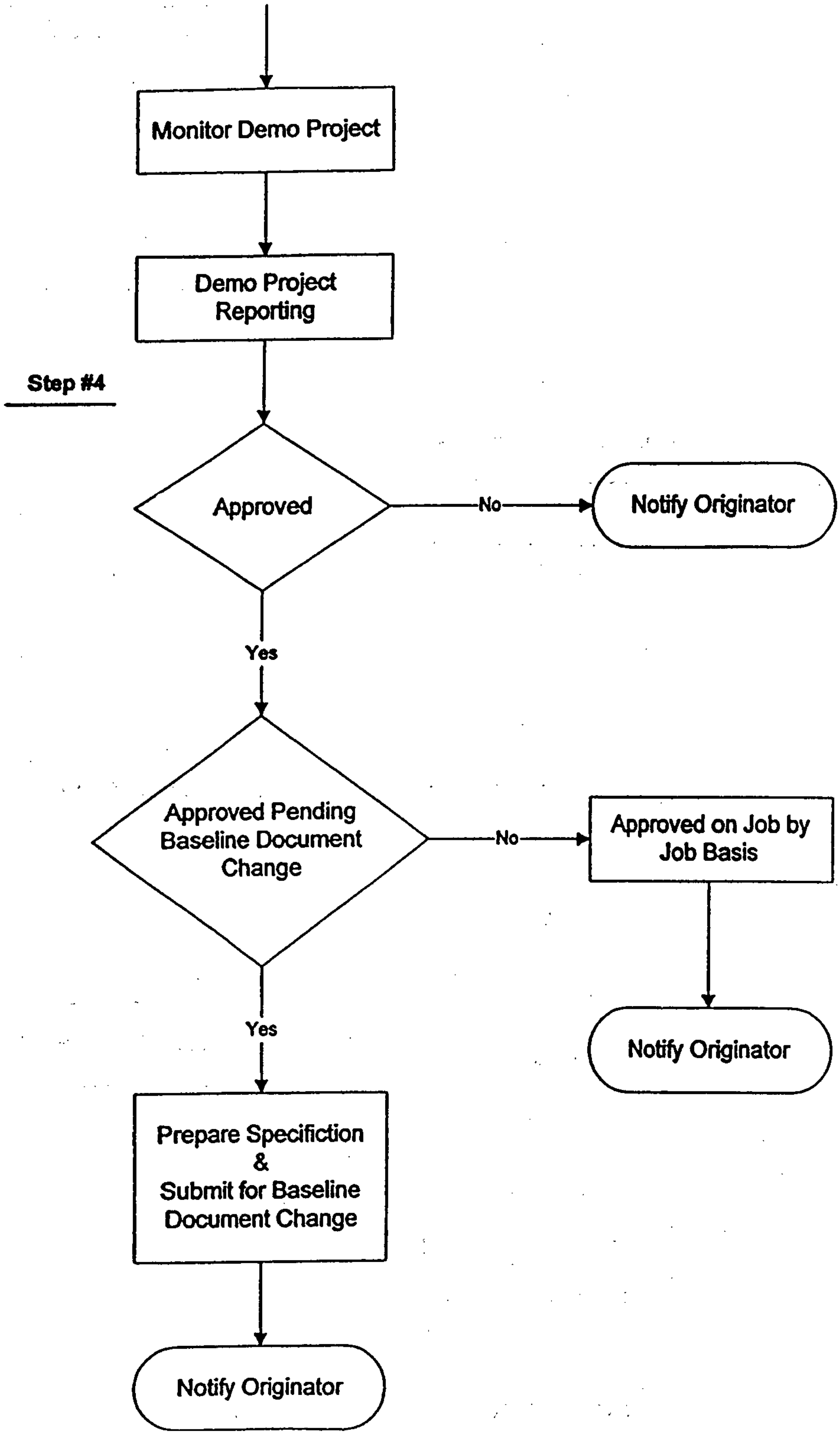
1. Initial screening,
2. Preliminary evaluation,
3. Demonstration project evaluation, and
4. Approval and specifications.

The flowchart illustrates the NTP evaluation process.

New Technologies and Products
Review, Evaluation and Approval Process




Covered by Existing Specification
Yes
Approval Pending Compliance Testing
No
Approval Job by Job
Yes
Notify Originator
No
Prioritization of Product
Request Formal Presentation (Optional)
Consensus for Evaluation
No
Notify Originator
Yes
Short Term Demo (1 yr.)
No
Refer to Research
Step #3
Yes
Selection of Demo Project (Interim Specification)
Determine Funding and Develop Work Plan

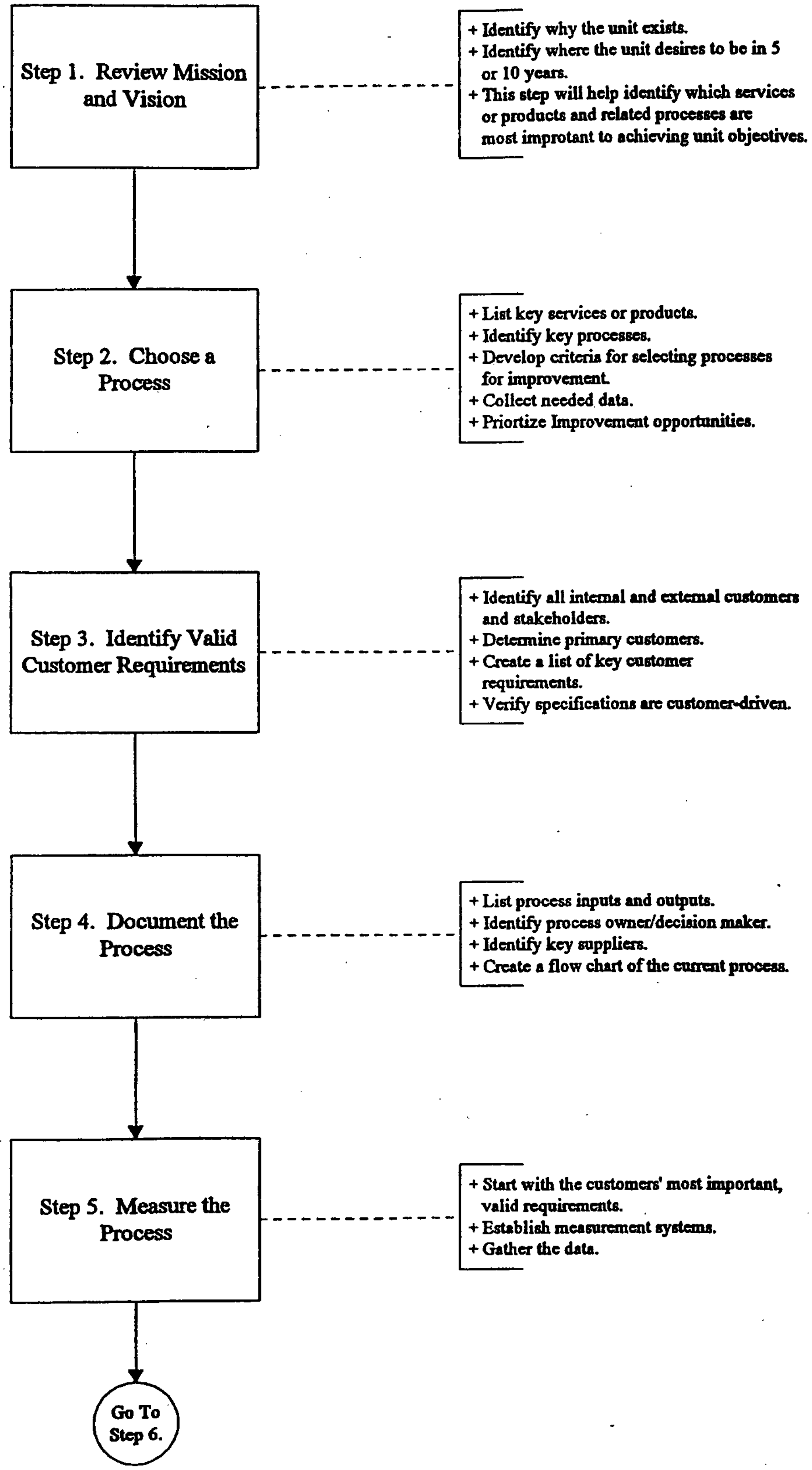

Monitor Demo Project
Demo Project Reporting
Step #4
Approved
No
Notify Originator
Yes
Approved Pending Baseline Document Change
No
Approved on Job by Job Basis
Notify Originator
Yes
Prepare Specifiction & Submit for Baseline Document Change
Notify Originator

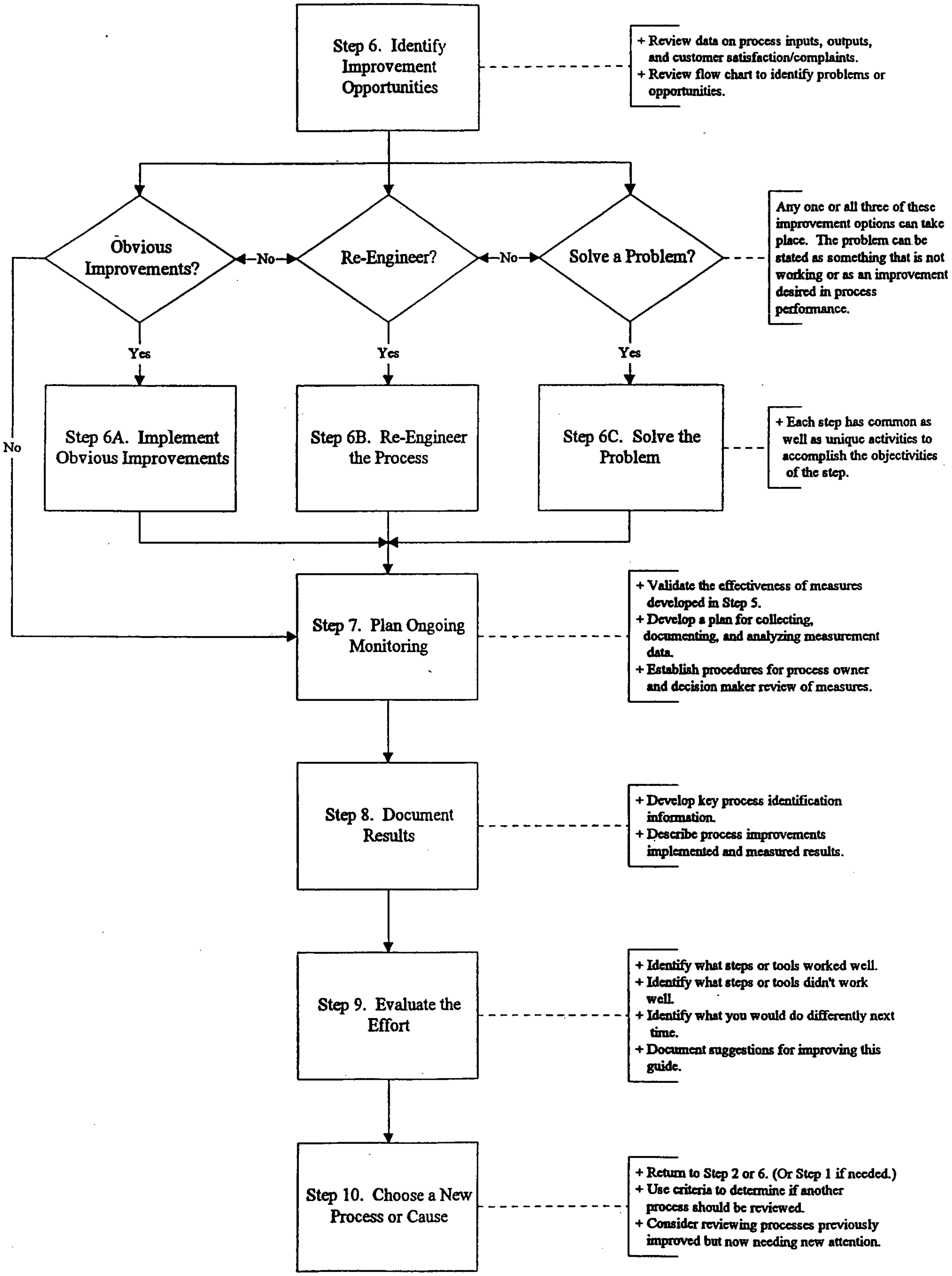
PROCESS IMPROVEMENT PROTOCOL (NORTH CAROLINA DOT)

The following flowchart is from *Continuous Process Improvement Guide* by NCDOT.

One of the key goals of NCDOT is to improve efficiency and employee involvement. The purpose of the guide is to assist officials in achieving this goal. The guide contains step-by-step instructions to assist in improvement of key processes within NCDOT. The flowchart illustrates the main steps and activities of the process.

PART 2. CPI PROCESS OVERVIEW




Step 6. Identify Improvement Opportunities
+ Review data on process inputs, outputs, and customer satisfaction/complaints.
+ Review flow chart to identify problems or opportunities.
Obvious Improvements?
No
Re-Engineer?
No
Solve a Problem?
Any one or all three of these improvement options can take place. The problem can be stated as something that is not working or as an improvement desired in process performance.
Yes
Yes
Yes
No
Step 6A. Implement Obvious Improvements
Step 6B. Re-Engineer the Process
Step 6C. Solve the Problem
+ Each step has common as well as unique activities to accomplish the objectivities of the step.
Step 7. Plan Ongoing Monitoring
+ Validate the effectiveness of measures developed in Step 5.
+ Develop a plan for collecting, documenting, and analyzing measurement data.
+ Establish procedures for process owner and decision maker review of measures.
Step 8. Document Results
+ Develop key process identification information.
+ Describe process improvements implemented and measured results.
Step 9. Evaluate the Effort
+ Identify what steps or tools worked well.
+ Identify what steps or tools didn't work well.
+ Identify what you would do differently next time.
+ Document suggestions for improving this guide.
Step 10. Choose a New Process or Cause
+ Return to Step 2 or 6. (Or Step 1 if needed.)
+ Use criteria to determine if another process should be reviewed.
+ Consider reviewing processes previously improved but now needing new attention.

TOOLS FOR IMPLEMENTING RESEARCH RESULTS (UTAH DOT)

The following list is from "Implementation Tools" by UDOT.

The document emphasizes the importance of implementing the results of research projects. It discusses the importance of incorporating implementation in the planning phase of any research study. This task can be accomplished by involving the Technical Advisory Committee (TAC) from the outset of any project. TAC consists of the end users of a research product. The review of the findings during and after completion of research by TAC is crucial for the success of implementation efforts. Significant importance is given to the communication of research results to users and to the organization as a whole. This communication could be accomplished through reports, newsletters, research briefs, training, conferences, and meetings, as shown in the following list.

UDOT
Implementation Tools

Written:

- Specifications
- Standards
- Policies & Procedures
- Newsletters
- Research reports

Meetings & Conferences:

- Training sessions
- Workshops & Demonstrations
- UDOT Research Retreat
- UDOT Engineer's Conference

Support Groups:

- Implementation Panels
- Technical Advisory Committee
- New Products Evaluation Panel
- Division/Region Staffs
- Utah Transportation Research Council
- Standards Committee
- Administrative Council

Evaluations:

- Experimental Features/Demonstration Projects
- Laboratory Testing

EVALUATION FORM (NORTH CAROLINA DOT)

The following evaluation form is from NCDOT.

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
Division of Highways

PRELIMINARY INFORMATION FOR NEW PRODUCT EVALUATION COMMITTEE

I. PRODUCT IDENTIFICATION

Date______________

Product Trade Name____

Product Model Number____

Alternate Names (use)____

II. PRODUCT CONTACT INFORMATION

Manufacturer_______________________________ Phone No.______________

Address____
Street City State Zip Code

Distributor/
Representative_____________________________ Fax No.______________

Contact Person_____________________________ Phone No.______________

Address____
Street City State Zip Code

III. PRODUCT DESCRIPTION

Describe Product____

____

Primary use (must apply to highway usage with documentation provided)__________

____

Outstanding features or benefits_____________________________________

____

Material composition or formulation__________________________________

____

Guarantees or Warranties____

PRELIMINARY INFORMATION FOR NEW PRODUCT EVALUATION COMMITTEE

Material specifications furnished by Manufacturer? Yes____No____Copy AttachedYes____No____

Plan drawings, picture, or sketch furnished by Mfg.? Yes___No___CopyAttached Yes____No___

Unit Cost-Material only______________Approximate Cost-Complete in place______________

Patented? Yes____No___Applied for Yes____No___Date_______ Proprietary? Yes____No____

Are instructions or directions for installation, application, or use available? Yes_______No______

Copy attached? Yes_______No_______ Will demonstration be provided? Yes______No______

Are educational courses or videos available? Yes_____No_____Royalty Cost_____________

Is Product New on the Market? Yes_____No_____It was in (year)________________________

Background description of Company and its product.________________________________

____

Are quantities limited? Yes____No___Will free sample be furnished upon request? Yes___No___

Has another office of the NC Department of Transportation been contacted? Yes______No______

Which office?____

IV. EVALUATION or TESTING INFORMATION

Meets requirements of following specifications: AASHTO____ASTM____Other_____________

Federal Specifications.____

____

Used by Highway Authorities or other agencies in other states.

Agency	Years in Use	Remarks

(Attach additional sheets if necessary)

Testing done by(agency, Indep. Lab., etc.)_________________________________

Evaluation status (pending, etc.)_______________________________________

PRELIMINARY INFORMATION FOR NEW PRODUCT EVALUATION COMMITTEE

Description of Lab Test Procedure____

Description of Lab Test Results____

Description of Field Test Procedure____

Description of Field Test Results____

Environmental considerations____

Availability: Seasonal_____Nonseasonal____Delivery at site_______weeks after receipt of order.

Does product have Hazardous materials? Yes____No____Describe:____________________

Alternate or comparison to existing product(s)________________________________

Product advantages - limitations____

Links or references____

Additional Information____

____

____

(Attach additional sheets if necessary)

Please attach applicable trade literature, test results, Material Safety Data Sheets(MSDS's), specifications, instructions, guarantees, etc.

Please send **FOUR copies** of this completed form, pamphlets, booklets, binders, etc., TO:

Original & copies of this form should be mailed to:	Packages should be sent to:
Mr. Dale Frantz, New Products Coordinator New Products Evaluation Committee N.C. Department of Transportation Design Services Unit P.O. Box 25201 Raleigh, NC 27611	New Products Evaluation Coordinator New Products Evaluation Committee N.C. Department of Transportation Design Services Unit 1020 Birch Ridge Drive Raleigh, NC 27610

The **Transportation Research Board** is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purpose of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation

TRANSPORTATION RESEARCH BOARD
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

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