DEMONSTRATING AND COMMUNICATING RESEARCH IMPACT

Preparing NIOSH Programs for External Review

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Sponsored by the National Institute for Occupational Safety and Health

RAND Safety and Justice
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Preface

The RAND Corporation undertook this analysis to assist the National Institute for Occupational Safety and Health (NIOSH) in developing and applying a framework for conducting external reviews of the impact of its research activities. NIOSH initiated the reviews to better ensure the applicability of its work in preventing work-related injuries and illnesses. The analysis is also intended to provide assistance to other federal research agencies facing similar concerns.

This book reports on phase II of the project, "Analytical and Operational Support for NIOSH External Program Review." In particular, it describes the methodology we developed to assist NIOSH programs in preparing for external review by the National Academies. It also details the use of logic models, outcome worksheets, and outcome narratives as key tools in preparing evidence packages that demonstrate and communicate the impact NIOSH research activities have had in contributing to reduction in hazardous exposures, occupational illnesses, injuries, and fatalities. This book should be of interest to mission-oriented federal research and development (R&D) agencies that are either planning for or undergoing external review; the program managers and research scientists within these agencies; program evaluators (public and private); non-R&D federal agencies interested in evaluating the outcomes of research programs; science policymakers; and research funders.

Other RAND publications that might interest the reader include the following:

- *The Returns from Arthritis Research*, Vol. 1: *Approach, Analysis and Recommendations* (Wooding et al., 2004)
- *Using Logic Models for Strategic Planning and Evaluation: Application to the National Center for Injury Prevention and Control* (Greenfield, Williams, and Eiseman, 2006).

The RAND Safety and Justice Program

This research was conducted under the auspices of the Safety and Justice Program within RAND Infrastructure, Safety, and Environment (ISE). The mission of ISE is to improve the development, operation, use, and protection of society's essential physical assets and natural resources and to enhance the related social assets of safety and security of individuals in transit and in their workplaces and communities. Safety and Justice Program research addresses occupational safety, transportation safety, food safety, and public safety—including violence, policing, corrections, substance abuse, and public integrity.

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Contents

Preface iii
Figures vii
Tables ix
Summary xi
Acknowledgments xix
Abbreviations xxi

CHAPTER ONE
Introduction 1
Evaluating the Impact of Research Programs 1
Expert Review 4
Demonstrating and Communicating the Impact of Research Programs 5
Purpose of This Book 6
Organization of This Book 7

CHAPTER TWO
Using Expert Evaluation to Measure the Impact of Federal Programs: The National Academies' Review of NIOSH 9
Overview of the National Institute of Occupational Safety and Health 9
Expert Review by the National Academies 12
The National Academies' Evaluation Framework 13
Criteria for Assessing Impact and Relevance 16
RAND's Role in Helping NIOSH Programs Prepare for External Review 17
Phase I: Research and Design 18
Phase II: Implementation 19

CHAPTER THREE
Logic Models 21
Elements of a Logic Model 22
Importance of Logic Models in Demonstrating and Assessing Impacts 25
Linking Program Operations to Program Strategy 26

Generating the Information for the Logic Model 27
Approaches for Addressing Research Complexity in the Logic Models 29
Representing the Role of Partners in Logic Models: The Mining and Construction Research Programs........ 30
Describing Multifaceted Research Programs: The Health Hazard Evaluation and Personal Protective Technology Programs 33
Concluding Thoughts 38

CHAPTER FOUR
The Outcome Worksheet 41
The Evolution of Historical Tracing 42
Developing Outcome Worksheets: Building from Logic Models 44
Gathering Data for the Outcome Worksheet 47
Analyzing Information in the Outcome Worksheet 48
Concluding Thoughts 51

CHAPTER FIVE
The Evidence Package 53
Communicating Impact 53
Communicating to a Different Audience 53
Communicating for a Different Purpose 55
The Structure of the Evidence Package 56
Using Outcome Worksheets to Prepare Outcome Narratives 57
Writing the Outcome Narrative 57

CHAPTER SIX
Future Considerations for the Improvement and Application of Tools 65
Limitations of the Tools 65
Other Uses for the Tools 68

APPENDIX
NIOSH Program Logic Model 71

References 73

Figures

S.1. Moving from the Logic Model to the Outcome Worksheet xiv
S.2. Relationship Among the Three Tools xvii
2.1. NIOSH Organizational Chart 10
3.1. Standard Elements for NIOSH Program Logic Models 22
3.2. Logic Models Distinguish Program Efforts from Effects 25
3.3. Logic Model Links Operations to Strategy 26
3.4. Linking Elements Within Logic Model Boxes 29
3.5. Logic Model for the NIOSH Construction Program 32
3.6. Logic Model for the NIOSH Mining Program 34
3.7. Logic Model for the NIOSH Health Hazard Evaluation Program 36
3.8. Logic Model for the NIOSH Personal Protective Technology Program 37
4.1. Moving from the Logic Model to the Outcome Worksheet 45
4.2. A Schematic of an Initial Draft of an Outcome Worksheet 48
4.3. Outcome Worksheet: Hearing Loss Prevention Program 50
4.4. A Schematic of a Final Draft of an Outcome Worksheet 51
5.1. Translating the Outcome Worksheet to the Outcome Narrative 58
6.1. Linking Tools for Demonstrating and Communicating Impact 66
6.2. Logic Model Template as a Program Management Tool 69
A.1. NIOSH Program Logic Model 72

Tables

2.1. NIOSH Research Program Portfolio 11
2.2. Suggested Outline for Evaluation Committee Reports 14
2.3. Scoring Criteria for Impact 16
2.4. Scoring Criteria for Relevance 17
5.1. A Tale of Two Audiences: Researchers and Evaluators 54

Summary

The evaluation of research impact is a topic of enduring interest to research funders and performers of research. *Research impact* refers to the contribution of research activities to desired societal outcomes, such as improved health, environment, economic, and social conditions. In recent years, this interest has grown because of governments' desire to understand the impact of publicly funded research for the purpose of budgeting and resource allocation decisions, both nationally and internationally. In the United States, the 1993 Government Performance and Results Act (GPRA) (Pub. L. No. 103-62) and the 2002 Program Assessment Rating Tool (PART) are the most recent manifestations of the public's concern about the payoff of federally funded research. These policies, which require all federal programs to conduct assessments of their own performance, present special challenges for research programs because of the methodological difficulty of measuring the impact of research.

The difficulties associated with tracking and measuring the societal outcomes of research has caused this area of evaluation to lag other types of evaluation that seek to assess other dimensions of research, such as quality, relevance, and productivity. Despite these difficulties, approaches to evaluating the impact of research have progressed substantially in the past decade. Technometrics, sociometrics, bibliometrics, value-mapping, expert review, and case studies represent both quantitative and qualitative means of assessing the benefits of research to industry, government, and the public.

Federal agencies often employ multiple types of expert review to evaluate research impact. In the past few decades, use of expert panels has become commonplace for evaluating larger units, such as research groups, institutes, and research programs. In addition to evaluating scientific merit, these panels often assess the socioeconomic impact of research.

Expert Review of NIOSH Programs by the National Academies

In September 2004, the National Institute for Occupational Safety and Health (NIOSH) contracted with the National Academies to conduct external reviews of up to 15 of its research programs. The purpose of the reviews was to judge the extent to which each program's research was relevant to real-world occupational safety and health (OSH) problems; contributed to reductions in occupational hazardous exposures, illnesses, and injuries; and was effective in targeting new research areas and identifying emerging issues.

Eight research programs were reviewed by individual evaluation committees (ECs) composed of persons with expertise appropriate to evaluating the specific program. In many cases, experts were recruited from stakeholder groups (such as labor unions and industry). Experts in technology transfer and program evaluation were also included. In conducting their evaluations, the ECs ascertained whether NIOSH is doing the right things (relevance) and whether those things are improving health and safety in the workplace (impact).

To maintain consistency in the evaluation across the independent ECs, the National Academies appointed a committee of 14 members, including persons with expertise in occupational medicine and health, industrial health and safety, industrial hygiene, epidemiology, civil and mining engineering, sociology, program evaluation, communication, and toxicology; representatives of industry and of the workforce; and a scientist experienced in international occupational-health issues. This committee, referred to as the Framework Committee, developed a guide to provide a common structure for the review of the different research programs. The guide, called the framework document, outlines the evaluation criteria to be used by the ECs, the information needs, and the specific evaluation questions to be considered.

The framework document recommended that the ECs consider the available evidence of reduced work-related risks and adverse effects (hazardous exposures, illnesses, fatalities, and injuries) and external factors related to the changes. A finding of high impact required the EC's judgment that the research program had contributed to these end outcomes. So, for example, *high impact* could mean that outcomes had occurred earlier than they otherwise would have or were better than they would have been in the absence of the research program. A finding of high impact could also result if external factors beyond NIOSH's control had impeded achievement of end outcomes. The criteria for assessing relevance centered on whether the program appropriately set priorities among research needs and the assessment of how engaged the program is in appropriate transfer activities.

NIOSH asked RAND to assist it in preparing for and engaging in external program reviews. Our activities took place in two phases: research and design (phase I) and implementation (phase II). In phase I, we met with other federal agencies to gain perspective about different approaches to external review; developed a set of guidance principles to assist NIOSH programs throughout the external review process; and created a detailed set of specifications for preparing a model package of information, or *evidence packages*, to give to the reviewers (Greenfield, Balakrishnan, et al., 2006). In phase II, we worked with selected NIOSH programs undergoing external review, which included assistance with preparing evidence packages. Phase II efforts led to the development of a set of tools that were instrumental to demonstrating and communicating the impact of research activities on achieving outcomes.

This document reports on phase II of the project. In particular, it describes the tools developed—logic models, outcome worksheets, and outcome narratives—and examines their use in preparing evidence packages.

Demonstrating Impact

Logic models and outcome worksheets were used primarily to help NIOSH programs demonstrate how their research was intended to achieve program outcomes. Each is discussed in more detail in this section.

Logic Models

A central challenge in demonstrating the impact of research programs is describing the path by which research achieves its intended outcomes (in NIOSH's case, reductions in work-related hazardous exposures, illnesses, or injuries). Logic models can help with this demonstration. A logic model is a visual depiction of the stages across which research inputs are translated into outcomes. Such depictions can help reviewers understand how research activities achieve societal objectives or impacts. Logic models provide a comprehensive view of a research program: what it does, whom it affects, and the expected outcomes that can form the basis of the evaluation. Logic models can also define the domain of analysis for evaluating impact. By showing the multiple contributors to any given end outcome, the logic model helps define the program's sphere of influence—i.e., for what the program can take credit and for what it can be held responsible.

There are several ways to develop and customize logic models for specific research programs. Because a logic model is an abstraction that omits detail for the sake of clarity of representation, the trade-off between detailed accuracy and clarity of presentation varies according to context and purpose. In developing logic models with NIOSH programs, clearly depicting the paths to outcomes was the priority. Thus, we maintained the linear flow of the logic model, using feedback loops and other divergent pathways only in rare cases. Moreover, these logic models were accompanied by text in the evidence packages, and many of the complex details that were omitted in the logic model were explained in these narratives.

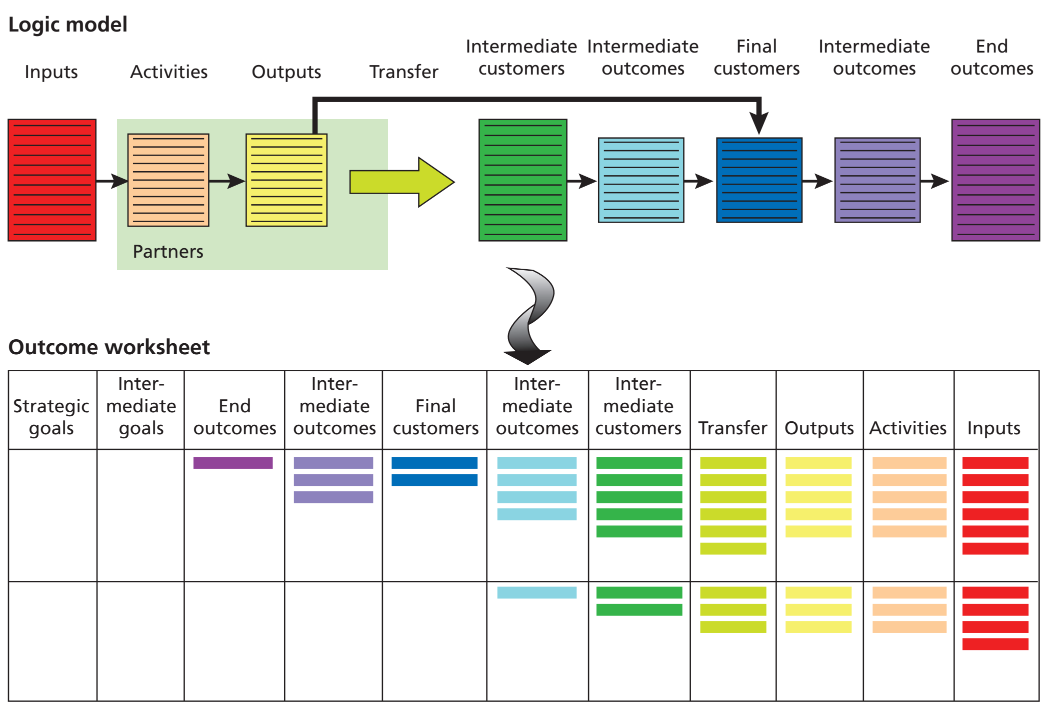
Outcome Worksheets

Logic models were used to assist NIOSH programs in presenting an overarching view of their programs and, in so doing, articulate their program theory. However, the evidence of impact needed for the evidence packages required descriptions of cases in which NIOSH programs achieved specific outcomes. The guidance we provided to NIOSH research programs for describing their path to outcomes is based on the historical tracing method. This method traces a series of interrelated events either going forward from the research activities to downstream outcomes or working backward from an outcome to precursor research. A tool that supported the use of this method was the outcome worksheet. An outcome worksheet is a spreadsheet that details how specific outcomes were achieved, based on the path described by the logic model. Figure S.1 illustrates the creation of the outcome worksheets from the logic model.

As shown in Figure S.1, the logic model begins with the "Inputs" box in red and ends with the "End outcomes" box in purple. The outcome worksheet (shown in the lower half of Figure S.1) includes the strategic and intermediate goals and reverses the order of the logic model elements, with the end outcomes at the far left end and the inputs at the right. The lines within each of the colored boxes represent the text that is typically included in the logic models.

We developed the outcome worksheet to assist NIOSH researchers in thinking through the causal linkages between specific outcomes and research activities,

Figure S.1
Moving from the Logic Model to the Outcome Worksheet



RAND *MG809-S.1*

determining the data needed to provide evidence of impact, and structuring the evidence in a systematic framework.

The first step in creating an outcome worksheet involves deciding whether to trace the research path forward (i.e., from research activities to outcomes) or backward. Forward tracing can capture a comprehensive view of a research project's or program's effects. Because the path leads from the research, the connection to the research is ensured. In contrast, backward tracing usually focuses on a single outcome of importance and follows the trail back through those developments that were critical in reaching the identified outcome. One implication of backward tracing is that it highlights activities that led to anticipated outcomes and may not capture the broader range of outcomes to which forward tracing may lead or may select only the most-positive cases of outcomes. In NIOSH's case, the National Academies' review focused on impact, and, as shown in Figure S.1, outcomes were the natural starting point, followed by customers, transfer activities, outputs, research activities, and, finally, inputs. Not only did this backward tracing reinforce the emphasis on outcomes, it also oriented researchers toward a collective body of research rather than on individual research projects.

In addition to identifying and structuring information, the format of the outcome worksheet also enabled quick review and analysis of a large amount of information. Finally, the outcome worksheet was critical in helping research programs prepare outcome narratives, our final tool, for communicating impact.

Communicating Impact

The logic models and the information from the outcome worksheets became part of a larger set of materials assembled in the form of an evidence package and submitted to the reviewers. A key component of the package was the outcome narrative, which helped to communicate the impact of NIOSH programs by describing how specific research activities contributed to intermediate or end outcomes. The outcome narrative served as our primary tool in communicating impact and is described in more detail in this section.

Outcome Narratives

The central purpose of the evidence package is to communicate to reviewers how research activities have contributed to societal outcomes. The reviewers were expected to use their expert judgment and knowledge of the field to evaluate the claims in the evidence package about the role of NIOSH programs in achieving intermediate outcomes (such as changes in workplace practices) or end outcomes (such as reductions in hazardous exposures). These claims of impact were presented in the form of outcome narratives that described specific instances of research that led to outcomes. To structure the outcome narrative, we again drew on the elements of the logic model.

Figure S.2 illustrates the connections among the tools we developed, including the outcome narrative.

The outcome narrative had five major sections, accompanied by specific questions.

- *Issue: What is the major societal problem?* The narrative should begin by defining the issue and its significance, why it exists, and who is affected.
- *Approach: What approach has been used to address this issue?* This section describes the research strategies that have been used to address the issue.
- *Outputs and Transfer: What were the major outputs from this research area? How and to whom were the products transferred?* This section highlights the relevance of outputs and transfer activities.
- *Intermediate Outcomes (or End Outcomes): What effect did the outputs have on the broader community?* This section emphasizes the effect of program outputs and establishes a causal thread by describing intermediate and final customers' responses to program outputs. The discussion plausibly links to some output.
- *What Is Ahead: What are some specific research activities currently under way or in planning in response to the problem?* This is an optional section that showcases activities or outputs currently in progress or in the planning stages. It should include work that has not yet achieved intermediate outcomes status but that is clearly on the horizon (three to five years out).

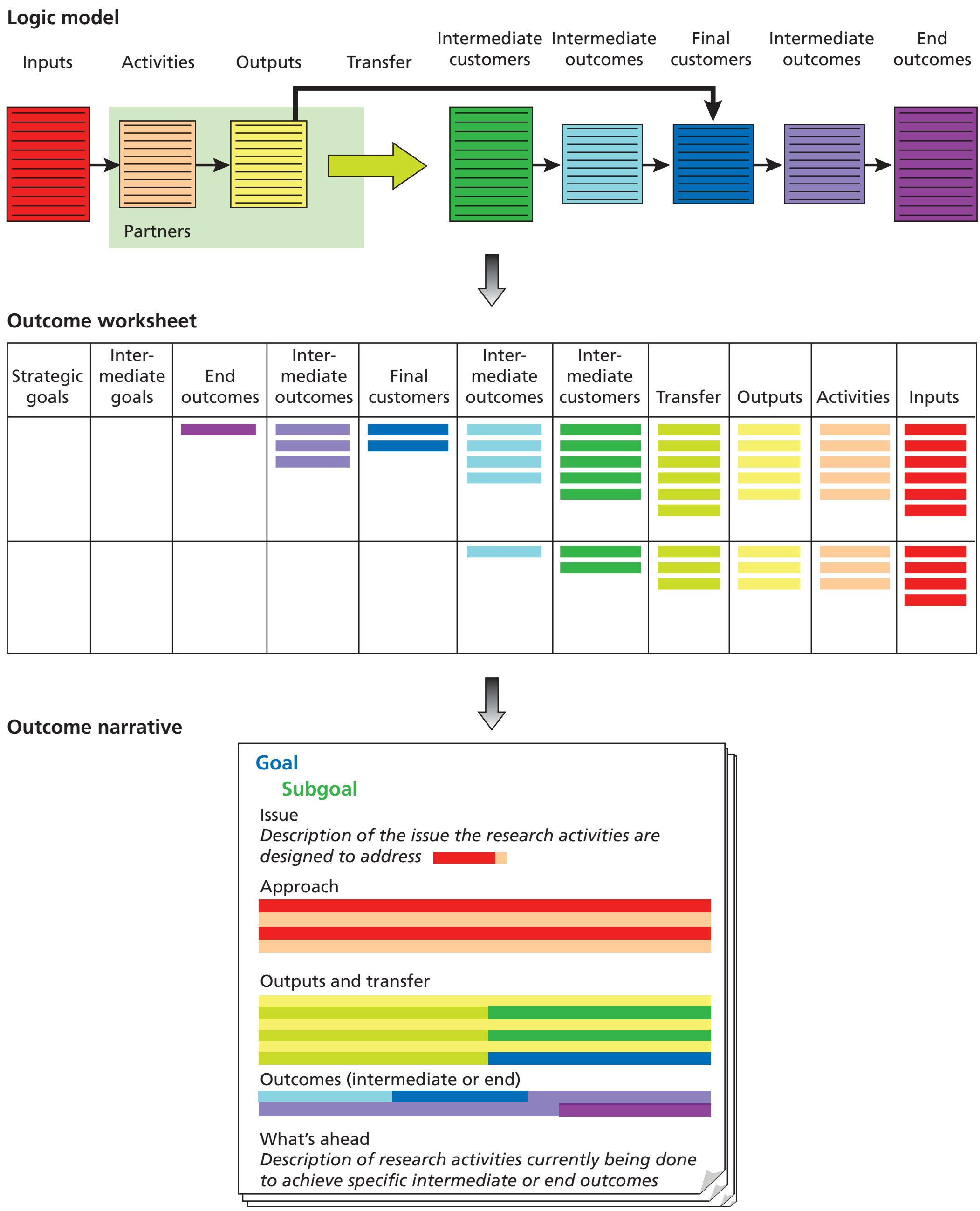
Other Applications of These Tools

The tools described in this book have uses beyond supporting preparations for external review. They can also be used by research programs to conduct outcome monitoring, which can assist program managers in thinking through the data they will need to demonstrate program effectiveness.

Logic models can also support project planning and management, as they provide a structure for determining whether existing strategic, intermediate, and annual goals are aligned with program operations. These goals can drive the development of measures that can gauge the progress of the program toward achieving outcomes.

The outcome worksheets are useful for determining the appropriate data required for outcome monitoring and tracking. Using these, research programs can identify which set of research activities have been linked to outcomes, assess the extent to which transfer activities have led to intended customer outcomes, and identify the range of intended and unintended outcomes from their outputs. Over time, these worksheets can become the foundation of a database that tracks uptake, adoption, and utility of research outputs by different customers. This could enable better strategic planning of transfer activities and working more effectively with partners at early project phases.

Figure S.2
Relationship Among the Three Tools



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Finally, the outcome narratives are useful tools for communicating impact to audiences beyond reviewers. An effective outcome narrative can convey the value of research to key stakeholders, who often prefer reading documents that get to the point quickly and clearly. The concise format and readable layout of the outcome narrative ensures that the investments to demonstrate impact can be accessed and appreciated by a broader community.

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Abbreviations

AFL-CIO	American Federation of Labor and Congress of Industrial Organizations
ANSI	American National Standards Institute
ARC	agricultural research center
ASTM	ASTM International (formerly, the American Society for Testing and Materials)
BLS	Bureau of Labor Statistics
CAD	computer-aided design
CDC	Centers for Disease Control and Prevention
CFOI	Census of Fatal Occupational Injuries
COPPE	Committee on Personal Protective Equipment
CPSC	Consumer Product Safety Commission
CPWR	Center for Construction Research and Training, formerly known as the Center to Protect Workers' Rights
CSC	Construction Steering Committee
DELS	Division of Earth and Life Studies
DHHS	U.S. Department of Health and Human Services
DHS	U.S. Department of Homeland Security
DoD	U.S. Department of Defense
DOI	U.S. Department of the Interior
DOL	U.S. Department of Labor

EC	evaluation committee
EPA	U.S. Environmental Protection Agency
ERC	education and research center
EU	European Union
FACE	Fatality Assessment and Control Evaluation
FSB	Field Studies Branch
FY	fiscal year
GPRA	Government Performance and Results Act
HETAB	Hazard Evaluations and Technical Assistance Branch
HEW	U.S. Department of Health, Education, and Welfare
HHE	Health Hazard Evaluation
IMIS	Integrated Management Information System
IOM	Institute of Medicine
ISO	International Organization for Standardization
LIUNA	Laborers' International Union of North America
MESA	Mine Enforcement and Safety Administration
MMWR	*Morbidity and Mortality Weekly Report*
MRI	magnetic resonance imaging
MSHA	Mine Safety and Health Administration
NFPA	National Fire Protection Association
NGO	nongovernmental organization
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NORA	National Occupational Research Agenda
NSF	National Science Foundation
OMB	Office of Management and Budget

OSH	occupational safety and health
OSHA	Occupational Safety and Health Administration
OSHAct	Occupational Safety and Health Act of 1970
OSTP	U.S. Office of Science and Technology Policy
PART	Program Assessment Rating Tool
PortMan	portfolio management
PPT	personal protective technology
r2p	research to practice
R&D	research and development
RCT	randomized controlled trial
RDRP	Respiratory Diseases Research Program
RIM	reaction injection molding
RQF	research quality framework
RVM	research-value mapping
SEI	Software Engineering Institute
TOP	targeted outcomes of programs
TRACES	Technology in Retrospect and Critical Events in Science
UBC	United Brotherhood of Carpenters and Joiners of America
UL	Underwriters Laboratories
USDA	U.S. Department of Agriculture

CHAPTER ONE

Introduction

Evaluating the Impact of Research Programs

Evaluating the impact—and, by extension, the benefits—of research to society has historically been of great interest to research funders, program managers, policymakers, researchers, policy analysts, and the public. However, given the methodological difficulties associated with tracking and measuring the societal outcomes of research, this area has lagged other types of evaluation that seek to assess other aspects of research, such as quality, relevance, and productivity. Some of the factors that complicate the evaluation of research impact include the following:

- the long time lag between the completion of a body of research and the achievement of its full impact, especially for basic research. It may take decades or more before research products are widely adopted and produce widespread benefits (Alston, Craig, and Pardey, 1998).
- the difficulty in attributing outcome effects to particular research causes. The connection between research and effects is diffuse and indirect. Impacts require inputs other than just the conclusion of a research and development (R&D) project and dissemination (Rip, 2001). The quality of research, the extent to which the research is diffused to those in a position to use this information to generate impacts, and the ability of research users to extract full value from it will all influence the final impact of research (Allen Consulting Group and Australia Department of Education, Science, and Training, 2005).
- the difficulty of collecting evidence of impact without undue selection bias for positive impact
- lack of well-articulated program theory that describes the path of how a program achieves its end outcomes.

Despite these factors, approaches to evaluating the impact of research have evolved substantially in the past decade.[1] Technometrics, sociometrics, bibliometrics, value-mapping, expert review, and case studies represent both quantitative and qualitative means of assessing the benefits of research to industry, government, or, more broadly, the public (Donovan, 2008). In 1994, a special issue of *Evaluation Review* discussed the strengths and weaknesses associated with current methods of assessing research impact. The authors concluded that, because research impact has many facets, its assessment must use as many methods, types of expertise, and approaches as are required to address these different facets (Kostoff, Averch, and Chubin, 1994). Different approaches that result in similar findings engender confidence in the overall results. Different approaches that produce conflicting results still have value and increase understanding when trying to determine the causes of the differences and resolve them. An important objective of this special issue was to increase interest in implementing research impact assessments. As recently as summer 2008, the journal *New Directions for Evaluation* covered the topic of assessing scientific research and acknowledged the need for new and improved methods of assessment, particularly those that can increase the quality of research that is done, reduce the cost of doing it, and lend public credibility to the manner in which it is funded (Coryn and Scriven, 2008).

Interest in research impact evaluations has also been spurred by the governments' desire to gauge the value of publicly funded research for budget and resource allocation decisions, both nationally and internationally. In the United States, the Government Performance and Results Act (GPRA) and the Program Assessment Rating Tool (PART) are the most recent manifestations of the public's concern about the payoff of federally funded research and have spurred growing interest in focusing on the impact of research programs and, more specifically, on outcome measures as a way of monitoring and determining impact.

Passed by Congress in 1993, GPRA's purpose is to improve the efficiency and effectiveness of federal programs by establishing a system to set goals for program performance and to measure results (Cozzens, 1996). Under this law, federal agencies must submit, to the Office of Management and Budget (OMB) and the Congress, long-range strategic goals, beginning with the fiscal year (FY) 1999 budget. GPRA requires that agencies identify goals for specific outcomes of their activities, develop performance measures to assess programmatic outputs and outcomes, gather the requisite data to evaluate performance measures, and report annually on progress toward goals. PART, which the George W. Bush administration introduced in 2002 to further the policy objectives of budget and performance integration, is a systematic method of assessing program performance across the federal government (OMB, 2008). It includes a series of diagnostic questions designed to provide a consistent approach to the evalu-

[1] The literature on evaluating the impact of research is extensive. An overview of this field can be found in Bozeman and Melkers (1993).

ation of federal programs.[2] Both PART and GPRA represent federal efforts to achieve more accountability for program outcomes. However, PART is much more explicit in calling for information on achieving outcomes, including independent evaluation as a method of determining impact. Evaluations are covered in two of the four sections of PART. Question 2.6, which is part of the Strategic Planning section, asks, "Are independent evaluations of sufficient scope and quality conducted on a regular basis or as needed to support program improvements and evaluate effectiveness and relevance to the problem, interest, or need?" In section IV, Program Results/Accountability, question 4.5 asks, "Do independent evaluations of sufficient scope and quality indicate that the program is effective and achieving results?" Evidence to support an answer of "yes" for question 2.6 should adhere to the following guidance:

> To receive a *Yes*, agencies must demonstrate that they have chosen and applied evaluation methods that provide the most rigorous evidence of a program's effectiveness that is appropriate and feasible. A program may satisfy this criterion if the agency and OMB determine that the program is in the process of developing new evaluation approaches that will provide the most rigorous evidence possible by a specified future date. The most significant aspect of program effectiveness is *impact*—the outcome of the program, which otherwise would not have occurred without the program intervention. (OMB, 2008, p. 30)

Questions 2.6 and 4.5 are clearly linked. Thus, in addition to meeting the criteria outlined for question 2.6, evidence to support an answer of "yes" for question 4.5 should take note of the following:

> Relevant evaluations would be at the national program level, rather than evaluations of one or more program partners, and would not focus only on process indicators such as the number of grants provided, or hits on a web site. . . . Evidence should include a summary discussion of the findings of an evaluation conducted by academic and research institutions, agency contracts, other independent entities, the Government Accountability Office, or Inspectors General. (OMB, 2008, pp. 59–60)

Although PART guidance points to the randomized controlled trial (RCT) as an example of the best type of evaluation to demonstrate actual program impact, RCTs are not suitable for every program and can generally be employed only under very specific circumstances (OMB, 2004). When assessment of program effectiveness is subject to high uncertainty, expert evaluation, a form of peer review, should be considered.

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[2] There is no standard definition for the term *program*. For purposes of PART, the OMB describes the unit of analysis (*program*) as (1) an activity or set of activities clearly recognized as a program by the public, OMB, or Congress; (2) having a discrete level of funding clearly associated with it; and (3) corresponding to the level at which budget decisions are made.

Program uncertainty can be defined and identified by the following situations and conditions (Averch, 2004, p. 293):

- A public agency has been operating a "program" for a number of years, and it cannot be certain about the effective quantity or quality of inputs it has bought during those years, and there is no clear way to measure these.
- The expected "benefits" or "outcomes" of the program are highly uncertain in the present or must occur in the future.
- The agency does not know with precision whether decision-relevant outcomes can be attributed to the inputs and the design of the program.

For many federal research programs, at least one (if not all) of these conditions is operative. Thus, most evaluations of research impact rely on some form of expert review. In the following section, we provide a brief discussion of expert review and describe how it has been used to evaluate research impact.

Expert Review

In 1999, the National Academies offered the following recommendations for the evaluation of basic and applied research:

> The most effective way to evaluate research programs is by expert review. The most commonly used form of expert review of quality is peer review. This operates on the premise that the people best qualified to judge the quality of research are experts in the field of research. This premise prevails across the research spectrum from basic research to applied research. (Committee on Science, Engineering, and Public Policy, 1999, pp. 9–10)

Most federal agencies typically use several types of expert-review methods, including (1) peer review, which is commonly used to make judgments about the careers of individual staff members, the value of publications, the standing of institutions, and the allocation of funds to individuals, organizations, and fields of inquiry; (2) relevance review, which is used to judge whether an agency's programs are relevant to its mission; and (3) benchmarking, which is used to evaluate the standing of an organization, program, or facility relative to another (Ruegg and Feller, 2003). However, in the past few decades, wide-scale use of peer-review panels has become commonplace to evaluate larger units, such as research groups, institutes, and research programs. In addition to scientific merit, these large-scale panels are often concerned with the socioeconomic impact of research (Coryn and Scriven, 2008). Thus, increasingly, the term *peer review* has been reserved for the more traditional review and assessment systems of scholarly communities, such as reviews of manuscripts for journals, and the term *expert panel* *evaluation* or *expert judgment* is used for the evaluations of research that go beyond the merit of individual instances or pieces of research, or of individual researchers (Coryn and Scriven, 2008).

There are two types of expert-panel evaluation: peer-panel evaluation and mixed-panel evaluation (Langfeldt, 2002). One or the other is commissioned often ad hoc, for evaluation at the program, institutional, or discipline level. Peer-panel evaluation uses only researchers qualified in the subject matter under review. When the expert-panel evaluation consists of both peers and other experts (for instance, experts on policy or commercialization of research), it is referred to as *mixed-panel evaluation*.

Panel reviews are the main method for evaluating the impact of European Union (EU) research programs (Arnold, Muscio, and Zaman, 2005). There have been a number of recent reviews exploring alternative methods for evaluating EU investments, such as bibliometrics, econometrics, and social analysis. However, the value of panels continues to be emphasized, and other methods have been advocated as a complement rather than a replacement (Boaz, Fitzpatrick, and Shaw, 2008). In the United States, mission agencies, such as the departments of Defense, Energy, and Agriculture, have used expert-panel review to strengthen their program-review processes since the 1980s and 1990s (Cozzens, 1999). These expert panels rely on the review of relevant materials on program activities and results to help them assess the extent to which research programs have had impact. Thus, research programs bear much of the responsibility for gathering and presenting data that provide evidence for the impact of their programs. Demonstrating and communicating impacts for the purposes of expert-panel evaluation is subject to many of the same methodological hurdles as evaluating research. The following section describes some of the issues associated with them.

Demonstrating and Communicating the Impact of Research Programs

The impact of research programs is assessed largely outside of the context of the researcher's scientific discipline and relies on the response of customers, stakeholders, and others to outputs from the research program. As such, it requires research programs to do more than document research outputs, such as research publications, journal articles, or conference presentations. Demonstrating impact involves following the trail of research beyond the production of outputs and gathering information that provides an "evidence base" to support claims of impact. While most research programs may be familiar and most comfortable with presenting outputs, it is more difficult to determine and collect the data needed on outcomes. For example, if an output from a research program is a stakeholder presentation, part of demonstrating impact is articulating the route of use of the presentation that contributed to changes in workplace practices. Tracing this route requires an understanding of the program theory of how the research is intended to achieve outcomes, which involves research transfer and use, rather than just production.

Communicating research impacts to an audience that includes nonresearchers can also present challenges. Many research programs are not accustomed to reporting to audiences outside of the scientific community. Communicating impact to audiences who are interested primarily in how research activities have served a broader community is different from writing for a research audience. Adapting the content, structure, and writing style for a more diverse audience is critical for making the case that research activities have contributed to outcomes.

As researchers are increasingly required to demonstrate the impact of their work, the number of specialized tools and models that offer useful ways of conceptualizing and describing impact has increased. Though many different frameworks are discussed in the literature, only a few are actually used in impact evaluations (Boaz, Fitzpatrick, and Shaw, 2008). The Buxton-Hanney payback framework of health research benefits, which consists of a five-category classification system for the benefits of research, is one such framework (Buxton and Hanney, 1996). The research impact framework, developed by researchers at the London School of Hygiene and Tropical Medicine, is another one (Kuruvilla et al., 2006). This framework covers a wide range of potential areas of health-research impact and standardizes ways of describing them, so that individual researchers without any specific training in research impact assessment could use the framework to describe the impact of their work. Finally, Australia's research-quality framework (RQF) is a research evaluation model that considers research impacts in addition to the conventional quality measures normally used in the academic community. The RQF was proposed as a panel-based exercise to evaluate both research excellence and the wider benefits of academic research for the nation and to allocate funds on the basis of outcomes (Donovan, 2008).

Purpose of This Book

In September 2004, the National Institute for Occupational Safety and Health (NIOSH) contracted with the National Academies to conduct reviews of up to 15 of its research programs. Between 2005 and 2008, eight such reviews were conducted. The purpose of the reviews was to judge the extent to which NIOSH science is (1) relevant to real-world occupational safety and health (OSH) problems; (2) meets the highest scientific quality standards for which it can strive; and (3) achieves the greatest impact that it possibly can (see Howard, 2005). The National Academies' external review relies on the use of expert panels to evaluate the impact and relevance of each of the research programs. To assist in preparation for the reviews, NIOSH asked RAND to develop and apply a methodology for preparing for external program reviews. As a result of our work with NIOSH, we have developed a set of tools that research programs generally can apply to demonstrate and communicate impact. Collectively, these tools offer research programs a methodology for conceptualizing their research pathways to outcomes, tracing specific cases of outcomes back to research activities, and creating a model package that concisely communicates the evidence of impact. This book describes the development and use of each of these tools. Because it was written prior to the completion of all of the reviews, this book does not include feedback from the programs on the tools or an assessment of the overall effectiveness of these tools in helping to prepare for external reviews. Moreover, it does not offer commentary on NIOSH's overall experience in the external review process or a critique of the National Academies' review process. Both of these topics are beyond the scope of this book.

Organization of This Book

The remainder of this book is organized as follows. Chapter Two describes the structure of the National Academies' external review and the criteria used to assess research impact and relevance. Chapter Three focuses on our core tool, the logic model, which we developed with each of the NIOSH research programs. The logic model depicted the path from research activities to outcomes and was designed to facilitate the reviewers' understanding of how the programs intended to achieve their end outcomes and demonstrate impact. Chapter Four describes the outcome worksheet, which was used to help the research programs trace specific outcomes back to research activities. This backward tracing is based on historical tracing, and, in Chapter Four, we discuss how this methodology has evolved and how we used it to map research impact. Chapter Five focuses on communicating impact and describes the structure and contents of the evidence packages that each research program submitted to the expert panel. A key component of the evidence package was the outcome narrative, which was used to tell the research story of impact. Finally, in Chapter Six, we draw conclusions and discuss the utility of these tools beyond preparation for external review.

CHAPTER TWO

Using Expert Evaluation to Measure the Impact of Federal Programs: The National Academies' Review of NIOSH

In this chapter, we provide a brief overview of NIOSH and describe the structure of the National Academies' external review and the criteria that were used to evaluate the agency's research programs. In addition, we also describe RAND's role in assisting NIOSH.

Overview of the National Institute of Occupational Safety and Health

NIOSH is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness (see NIOSH, undated[a]). NIOSH is part of the Centers for Disease Control and Prevention (CDC) in the U.S. Department of Health and Human Services (DHHS). The main legislative underpinnings of NIOSH are the Federal Coal Mine Health and Safety Act of 1969 (Pub. L. No. 91-173, amended by Pub. L. No. 95-164 in 1977 or MSHAct; also known as the Coal Act) and the Occupational Safety and Health Act of 1970 (Pub. L. 91-596; also known as the OSHAct). The Coal Act was passed in the aftermath of a devastating coal-mine explosion that occurred in Farmington, West Virginia, in 1968. It took the lives of 78 miners and crystallized public opinion that stronger measures were needed to protect coal miners at work. Activities required by the Coal Act were split between the U.S. Department of Health, Education, and Welfare (HEW; now DHHS), which engaged in nonregulatory activities, such as health screening and research, and the Mine Enforcement and Safety Administration (MESA) in the U.S. Department of the Interior (DOI), which engaged in developing and enforcing workplace safety and health regulations in the mining industry. After its creation by the OSHAct, NIOSH assumed the health screening and research responsibilities specified under the Coal Act. When the Coal Act was amended in 1977, the Mine Safety and Health Administration (MSHA) in the U.S. Department of Labor (DOL) replaced MESA.

The OSHAct created NIOSH and the Occupational Safety and Health Administration (OSHA). OSHA is in the DOL and is responsible for developing and enforcing workplace safety and health regulations. NIOSH, in DHHS, was established to help ensure safe and healthful working conditions by providing research, information, education, and training in the OSH field.

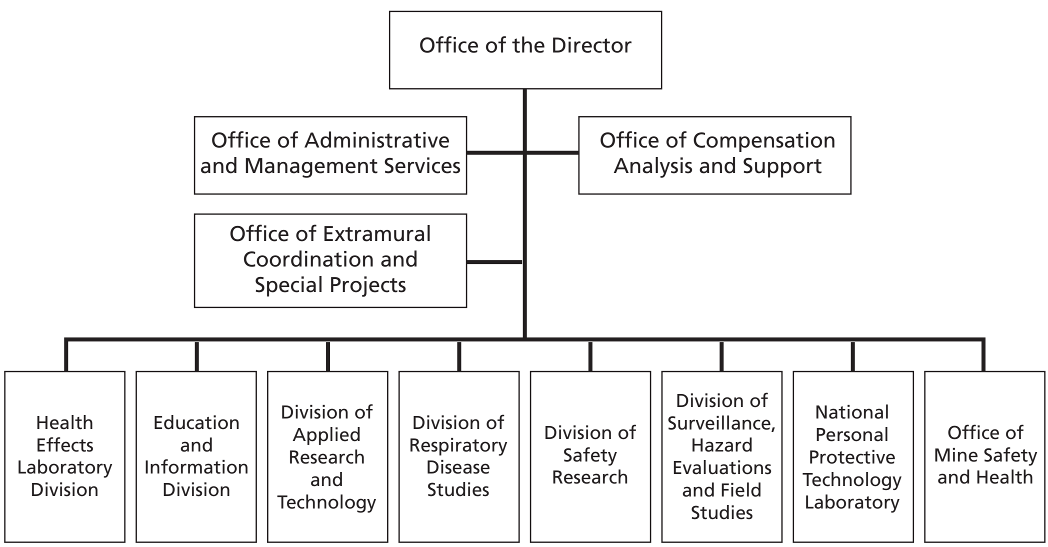
The main organizational units of NIOSH are divisions, laboratories, and offices (see Figure 2.1). These are a mixture of disease- and injury-specific divisions (respiratory diseases, safety research), expertise-specific divisions (applied research and technology, laboratory research, surveillance and field studies, education and information dissemination), and industry-specific units (mining).

The divisions, laboratories, and offices are geographically dispersed in Cincinnati, Ohio; Morgantown, West Virginia; Pittsburgh, Pennsylvania; Spokane, Washington; Denver, Colorado; and Anchorage, Alaska. NIOSH leadership is located in Washington, D.C., and Atlanta.

As shown in Table 2.1, the NIOSH research program portfolio is organized into eight sector programs that represent industrial sectors and 24 cross-sector programs organized around adverse health outcomes, statutory programs, and global efforts (NIOSH, 2008a).

Research programs are spread across the organizational units in NIOSH. Thus, a research program is based on a matrix approach, rather than a unit-based approach, and is not an identifiable entity in the NIOSH organizational chart. For example, the research activities in the Hearing Loss Prevention program are conducted in at least four different divisions of NIOSH. Preparation for external reviews of these matrixed

Figure 2.1
NIOSH Organizational Chart



SOURCE: DHHS (2008).

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Table 2.1
NIOSH Research Program Portfolio

Type	Program
NORA sector	Agriculture, Forestry, and Fishing
	Construction
	Healthcare and Social Assistance
	Manufacturing
	Mining (includes Oil and Gas Extraction subsector)
	Services
	Transportation, Warehousing, and Utilities
	Wholesale and Retail Trade
NIOSH cross-sector	Authoritative Recommendations
	Cancer, Reproductive, and Cardiovascular Diseases
	Communications and Information Dissemination
	Economics
	Emergency Preparedness and Response
	Engineering Controls
	Exposure Assessment
	Global Collaborations
	Health Hazard Evaluation (HHE)
	Hearing Loss Prevention
	Immune and Dermal Diseases
	Musculoskeletal Disorders
	Nanotechnology
	Occupational Health Disparities
	Personal Protective Technology (PPT)
	Prevention Through Design
	Radiation Dose Reconstruction
	Respiratory Diseases
	Small Business Assistance and Outreach
	Surveillance
	Training Grants

Table 2.1—Continued

Type	Program
NIOSH cross-sector (continued)	Traumatic Injury
	Work Organization and Stress-Related Disorders
	Worklife Initiative

SOURCE: NIOSH (2008a, p. 16).

programs required the programs to gather information from across the organizational units. Another issue was program overlap. Some research activities (e.g., research to develop standardized methods) were logically reportable (and sometimes actually reported) by more than one program.

Expert Review by the National Academies

The NIOSH charge to the National Academies was to review its programs to assess their contributions to improving health and safety in the workplace. Specifically, the National Academies were asked to evaluate impact, relevance, and progress in identifying emerging research areas through the following tasks:

- assessment of the program's contribution, through OSH research, to reductions in workplace hazardous exposures, illnesses, or injuries through
  - an assessment of the relevance of the program's activities to the improvement of OSH
  - an evaluation of the impact that the program's research has had in reducing work-related hazardous exposures, illnesses, and injuries
- assessment of the program's effectiveness in targeting new research areas and identifying emerging issues in OSH most relevant to future improvements in workplace protection.

In response to the charge, the Institute of Medicine (IOM) and the Division of Earth and Life Studies (DELS) of the National Academies conducted evaluations of eight programs. Each program was reviewed by a separate evaluation committee (EC) composed of persons with expertise appropriate to evaluating the specific NIOSH research programs; in some cases, this included representatives of stakeholder groups (such as labor unions and industry) and experts in technology transfer and program evaluation. In conducting their evaluations, the ECs ascertained whether NIOSH is doing the right things (relevance) and whether those things are improving health and safety in the workplace (impact).

The ECs could choose among three general time frames for their review: (1) 1970–1995, (2) 1996–2005, or (3) after 2005. These time frames are associated with the National Occupational Research Agenda (NORA). NORA is a partnership program to stimulate innovative research and improved workplace practices. Unveiled in 1996, NORA is an effort to guide and coordinate research nationally, not only for NIOSH but for the entire OSH community (NIOSH, 2008b). Diverse parties collaborated to identify the most-critical issues in workplace safety and health. Partners then worked together to develop goals and objectives for addressing those needs. Thus, the earliest period (1970–1995) is considered the pre-NORA time frame and represents the period from the founding of NIOSH to the initiation of the NORA process. The second and third time frames refer to the first and second decades of NORA, respectively.

As part of their review, the ECs conducted information-gathering sessions to obtain information from the NIOSH research program that was being reviewed, stakeholders directly affected by the NIOSH research, and relevant independent parties. For example, in the review of the Mining program, the EC interacted with more than 40 Mining program employees and heard 17 presentations by NIOSH and the Mining program and nine stakeholder presentations during an open-session meeting. This included a presentation from the acting director of MSHA, labor-union representatives, equipment manufacturers, and training consultants. On average, each EC consisted of 10 members and met three times during the course of the review. To provide the final assessment of the research program's impact and relevance (charge 1), the ECs rated the program's performance on a five-point scale in which 1 is the lowest and 5 is the highest rating.[1] Only single-integer values could be assigned. In addition to the numerical scores, final program ratings were supported by reviewers' explanations of the scores. Although the research programs were not rated on charge 2, the ECs responded to this charge by providing a qualitative, narrative assessment of the program's efforts and suggestions about emerging issues that the program should be prepared to address. At the conclusion of the review, the ECs prepared a final report for NIOSH that followed the standard template shown in Table 2.2.

The National Academies' Evaluation Framework

To maintain consistency in the evaluation across the independent ECs, the National Academies appointed a committee of 14 members (the Framework Committee), including persons with expertise in occupational medicine and health, industrial health and safety, industrial hygiene, epidemiology, civil and mining engineering, sociology,

[1] Tables 2.3 and 2.4 provide full descriptions of each numerical value.

Table 2.2
Suggested Outline for Evaluation Committee Reports

Section	Description
I. Introduction	This section should be a brief descriptive summary of the history of the program (and subprograms) being evaluated with respect to pre-NORA, NORA 1, and current and future plans of the research program presented by NIOSH. It should present the context for the research on safety and health; goals, objectives, and resources; groupings of subprograms; and any other important pertinent information.
II. Evaluation of Programs and Subprograms (charge 1)	A. Evaluation summary (should include a brief summary of the evaluation with respect to impact and relevance, scores for impact and relevance, and summary statements)
	B. Strategic goals and objectives (should describe assessment of the program and subprograms for relevance)
	C. Review of inputs (should describe adequacy of inputs to achieve goals)
	D. Review of activities (should describe assessment of the relevance of the activities)
	E. Review of research program outputs (should describe assessment of relevance and potential usefulness of the research program)
	F. Review of intermediate outcomes and causal impact (should describe assessment of the intermediate outcomes and the attribution to NIOSH and include the likely impacts and recent outcomes in the assessment)
	G. Review of end outcomes (should describe the end outcomes related to health and safety and provides an assessment of the type and degree of attribution to NIOSH)
	H. Review of other outcomes (should discuss health and safety impacts that have not yet occurred; beneficial social, economic, and environmental outcomes; and international dimensions and outcomes)
	I. Summary of ratings and rationale
III. NIOSH Targeting of New Research and Identification of Emerging Issues (charge 2)	The EC should assess the progress that the NIOSH program has made in targeting new research in OSH and whether the NIOSH program has identified emerging issues that appear especially important in terms of relevance to the mission of NIOSH and should respond to NIOSH's perspective and add its own recommendations.
IV. Recommendations for Program Improvement	On the basis of the review and evaluation of the program, the EC may provide recommendations for improving the relevance of the NIOSH research program to health and safety conditions in the workplace and the impact of the research program on health and safety in the workplace.

SOURCE: National Academies (2007, p. 35).

program evaluation, communication, and toxicology; representatives of industry and of the workforce; and a scientist experienced in international occupational-health issues to develop a guide and provide a common structure for the review of the different research programs. The ensuing document, called the framework document (National

Academies, 2007),[2] defines the evaluation framework developed by the Framework Committee and outlines the evaluation criteria to be used by the ECs, the information needs, and the specific evaluation questions to be considered.

The Framework Committee used the NIOSH logic model (see Appendix A) to develop a flow chart to outline the scope and steps of an EC evaluation.[3] The flow chart breaks the NIOSH logic model into discrete, sequential program components to be characterized or assessed by the ECs. These components are summarized here:[4]

- *Review of major program-area challenges:* independent assessment by EC members to compare with NIOSH program-area goals
- *Review of strategic goals and objectives driving current program:* assessment of NIOSH process to select program goals, evaluation of goals selected by NIOSH, comparison with EC assessment of challenges
- *Review of inputs:* assessment of inputs consisting of planning and production inputs and including EC consideration of the degree to which allocation of funding and personnel was commensurate with resources needed to conduct the research
- *Review of activities:* assessment of activities including both research and transfer activities—the former to determine whether they are consistent with program goals, objectives, and major challenges of the research program, and the latter to determine whether the program appropriately targets outputs in a manner that will have the greatest impact
- *Review of outputs:* qualitative assessment of relevance and utility of outputs; the outputs of a highly ranked program will address needs in high-priority areas, contain new knowledge or technology that is effectively communicated, contribute to capacity-building inside and outside NIOSH, and be relevant to the pertinent populations
- *Review of intermediate outcomes:* review of responses by NIOSH stakeholders to NIOSH products, such as how widely products have been used or programs implemented or whether products have resulted in changes in the workplace or facilities by its peers
- *Review of end outcomes:* assessment of NIOSH's contribution to improvements in workplace health and safety, including decreases in injuries, illnesses, deaths, and exposures to risk; if there is no direct evidence of improvements in health

[2] This is the second and most recent version of the framework document that was used for NIOSH program reviews. The first version, dated December 19, 2005, was developed during the reviews of the Hearing Loss Prevention and Mining programs.

[3] The NIOSH logic model can be found in Appendix A. Logic models are defined and discussed in detail in Chapter Three.

[4] The complete discussion of each program component can be found in the National Academies (2007) framework document.

and safety, intermediate outcomes may be used as proxies for end outcomes as long as the ECs can qualify their findings

- *Review of potential outcomes:* assessment of other outcomes, including beneficial changes that have not yet occurred; social, economic, security, or environmental outcomes; and the impact that NIOSH has had on international occupational safety and health.

Criteria for Assessing Impact and Relevance

The ECs were expected to use their expert judgment to rate the relevance and impact of the overall research program. In assessing overall impact, the framework document recommended that the ECs consider the available evidence of changes in work-related risks and adverse effects and external factors related to the changes. Moreover, the ECs were advised to evaluate the impact of the research activities separately from the impact of the transfer activities. Transfer activities occur in two contexts: NIOSH efforts to translate intellectual products into practice and stakeholder efforts to integrate NIOSH results into the workplace (National Academies, 2007). High-impact assessments required the EC's judgment that the research program had contributed to outcomes—for example, the determination that outcomes would have occurred earlier or are better than they would have in the absence of the research program or that outcomes would have occurred were it not for external factors beyond NIOSH's control or ability to plan around. The criteria for scoring impact are shown in Table 2.3.

Table 2.3
Scoring Criteria for Impact

Score	Criterion
5	Research program has made major contributions to worker health and safety on the basis of end outcomes or well-accepted intermediate outcomes.
4	Research program has made some contributions to end outcomes or well-accepted intermediate outcomes.
3	Research program activities are ongoing and outputs are produced that are likely to result in improvements in worker health and safety (with explanation of why not rated higher). Well-accepted outcomes have not been recorded.
2	Research program activities are ongoing and outputs are produced that may result in new knowledge or technology, but only limited application is expected. Well-accepted outcomes have not been recorded.
1	Research activities and outputs do not result in or are not likely to have any application.
NA	Impact cannot be assessed; program not mature enough.

SOURCE: National Academies (2007, p. 33).

The criteria for assessing relevance focused on the EC's assessment of whether the program appropriately set priorities among research needs and the assessment of how engaged the program is in the appropriate transfer activities. The scoring criteria for relevance are shown in Table 2.4.

Table 2.4
Scoring Criteria for Relevance

Score	Criterion
5	Research is in high-priority subject areas and NIOSH is significantly engaged in appropriate transfer activities for completed research projects or reported research results.
4	Research is in priority subject areas and NIOSH is engaged in appropriate transfer activities for completed research projects or reported research results.
3	Research is in high-priority or priority subject areas but NIOSH is not engaged in appropriate transfer activities, or research focuses on lesser priorities but NIOSH is engaged in appropriate transfer activities.
2	Research program is focused on lesser priorities and NIOSH is not engaged in or planning some appropriate transfer activities.
1	Research program is not focused on priorities and NIOSH is not engaged in transfer activities.

SOURCE: National Academies (2007, p. 31).

RAND's Role in Helping NIOSH Programs Prepare for External Review

RAND provided operational and analytical assistance to NIOSH programs in the external review process. RAND's activities took place in two phases: research and design (phase I) and implementation (phase II). Each phase consisted of the following activities:

- an examination of the experiences of other federal agencies in carrying out external review; development of a set of guidance principles to assist NIOSH programs throughout the external review process; and creation of a detailed set of specifications for preparing a model package of information or "evidence packages" to give to the reviewers (Greenfield, Balakrishnan, et al., 2006)
- development of a methodology to assist selected NIOSH programs undergoing external review and guidance on preparing evidence packages.[5]

[5] In Greenfield, Balakrishnan, et al. (2006), this was referred to as a *submission package*.

Phase I: Research and Design

In phase I, we examined the experiences of other federal research agencies to gain perspective about different approaches to external review. Given a significant time constraint, we selected a small subset of federal research agencies using the following criteria:

- experience with external review, especially relating to impact[6]
- points of commonality with NIOSH, e.g., an application-oriented perspective
- reputation for excellence or "trendsetting."

On this basis, we developed a short list of agencies that have undergone external reviews of their research programs, consisting of the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), the U.S. Department of Agriculture (USDA), the National Institutes of Health (NIH), and the National Science Foundation (NSF).

To complement the agencies' perspectives, we also met with staff of the OMB. In contrast to the other five agencies, the OMB leads the administration's PART process and, in some instances, uses the results of the agencies' external reviews as inputs to that process. Moreover, the OMB has helped to shape the administration's position on external review.

Given our intent to develop guidance for future reviews, we solicited the discussants' views on each of the following topics: (1) the dimensions of external reviews, including program definitions and bases for assessment; (2) the internal management of external review processes, including the form and extent of the program's interactions with external reviewers; (3) the specific elements of the program's evidence packages to reviewers, including program data and data analysis; and (4) the results of reviews, including both the efficiency and effectiveness of the process and whether the process yielded administratively actionable and useful findings.

The results of our analysis from phase I indicated four broad principles for engaging in external reviews of impact. First, NIOSH should define programs for the best possible fit with mission and goals; however, it should also set appropriate expectations for programs of different composition, size, and maturity. Second, NIOSH should centralize coordination of the review process. Centralization will allow NIOSH to better track the flow of information to and from reviewers and to establish institutional memory. Third, and most directly related to the issue of assessing impact, NIOSH should use its evidence package to tell the program's research story. The story, or *research narrative*, should articulate answers to a series of key questions, such as, "What

[6] As discussed in Chapter One, many federal agencies undertake external review, often referred to as *peer review*, to determine the scientific merit of incoming research proposals (e.g., responses to requests for applications, requests for proposals, and program announcements) and to assess the quality of research results and outputs (such as papers and methods); however, relatively few undertake external review to assess impact.

path is the program taking and why? What are the program's primary inputs, activities, outputs, customers, and intended outcomes? How does this path support or relate to the program's strategy—its mission and goals? What are the program's boundaries and responsibilities? How does or will research contribute to intended outcomes?" Quantitative and qualitative data should be used to validate the research narrative by demonstrating progress along the path and by establishing the research's potential or actual contribution to intended outcomes.

The findings from this first phase also indicated that logic models are often used to guide the research narrative. As will be explained in more detail in Chapter Three, a logic model offers a simplified visual representation of the research path, starting with inputs and then progressing to activities, outputs, customers, and intended outcomes. We identified at least three roles for the logic model in external reviews. First, it can serve as a communication device. It can provide reviewers with a clear image or map of the program's operations and intent. As such, it can also provide a strong signal that the program understands its purpose and is on track. Second, it can clearly identify program boundaries and responsibilities, thereby clarifying the meaning of *impact* as it relates to the program. Third, it can provide a tool for identifying and structuring evidence. A program can link qualitative and quantitative indicators of progress to each step along the path, starting with inputs and finishing with intended outcomes.

The agency representatives with whom we met also provided some specific recommendations about particular kinds of evidence to support the research narrative. They said that evidence should include planning documents, lists of clients, lists of facilities and offices, budget information, bibliometric data, conference materials, bibliographies from criterion documents, research summaries, state-of-science assessments, and, importantly for NIOSH, examples of research contributions to intended outcomes, including client use of research. Evidence may also take the form of anecdotal narratives, potentially supplemented by customer surveys or other forms of customer feedback and external validation. In addition, submitted evidence needs to be shaped such that the relevance and context are apparent. Simply handing over volumes of information to external reviewers without explanation was not considered to have been helpful in other reviews.

Phase II: Implementation

The second phase of our project, the implementation phase, consisted of providing analytical and operational support to seven of the eight NIOSH research programs undergoing review: Hearing Loss Prevention, Mining, Respiratory Diseases, Traumatic Injury, Construction, Personal Protective Technology, and Health Hazard Evaluation. On average, we worked with each program for nine months. During this time, we assisted in the development of a program logic model and outcome worksheets and provided guidance for collection and presentation of evidence for the evidence package. Our assistance also included the review of initial and final drafts of the evidence package. Chapters Three, Four, and Five of this book describe the development and use of the tools from the implementation phase.

CHAPTER THREE

Logic Models

One of the central challenges in demonstrating impact is describing the path by which a program achieves its end outcomes. In the case of NIOSH programs, this would consist of a description of how NIOSH research investments, activities, and products *contribute* to a reduction in occupational injuries, illnesses, or fatalities.[1] Most research programs are a complex maze of activities that include feedback loops, forked paths, and iterative cycles. Simplifying this maze into a more linear path is critical for evaluating the impact of a research program. Thus, the starting point for our implementation phase was the development of a program logic model that served as a blueprint for describing a program's operational path. As a blueprint, the logic model lays out the program's plan for how resources, activities, and outputs lead to outcomes. However, the logic model does not claim to provide attribution of outcomes to activities. Attribution involves firmly establishing causal links between observed changes and specific interventions, typically through the use of experimental or quasi-experimental research designs that rely on some controlled comparison. These research designs are often used at an individual activity or project level. However, attempting to prove attribution at a program level would be a difficult undertaking, given the number of factors outside the program that can influence the achievement of outcomes. Thus, the program logic model presents the program's theory of how research activities lead to outcomes (Wholey, 1983).

This chapter draws on our work with NIOSH programs to describe the development of program logic models. In the chapter, we describe some of the issues that surfaced in trying to describe complicated research processes within the boundaries of the logic model. In so doing, we hope to address concerns about the limitation of logic models and provide suggestions and recommendations for representing contextual nuances in logic models.

[1] Based on John Mayne's (1999) approach of contribution analysis, as a way of measuring the performance of public-sector programs. This type of analysis provides information on the program's contribution to the outcomes it is trying to influence and uses a result chain to illustrate what is supposed to happen as a result of the activities undertaken and the outputs produced.

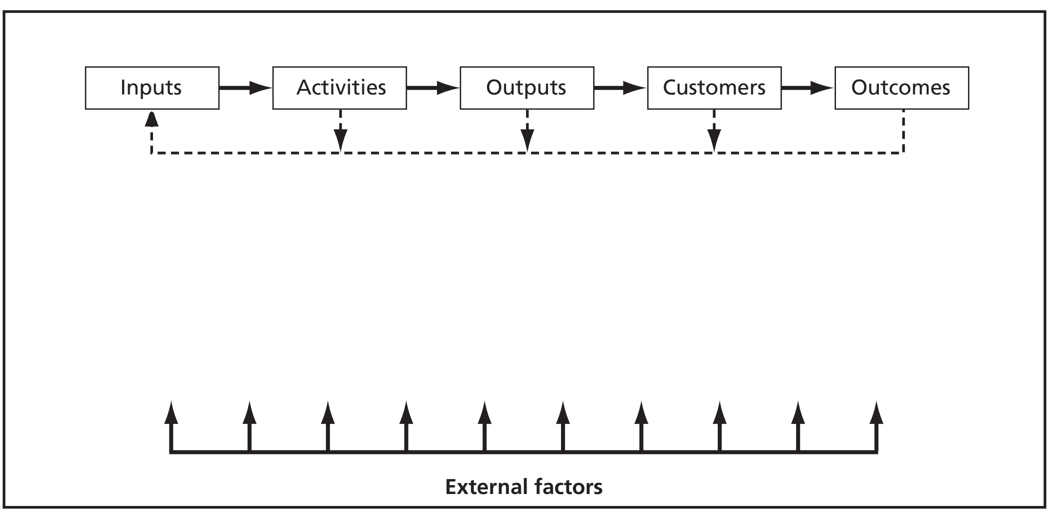
Elements of a Logic Model

A logic model is a visual depiction of how a research program will work under certain environmental conditions to solve problems (Bickman, 1987). As such, it can be used to communicate to customers and other stakeholders a program's intended outcomes and how resources and activities will be used to achieve those outcomes. The logic models that we developed with the NIOSH research programs were based on the standard core elements described in this section (see Figure 3.1).

Inputs are resources that both support and guide program activities. Our logic models distinguish between production resources (i.e., those resources that were used to support program activities, such as funding, staff, laboratory facilities and equipment) and planning resources (i.e., those resources that help to determine which activities should be undertaken). Planning resources include strategic planning documents, surveillance and risk-factor assessment, legislative mandates, and stakeholder input.

Activities are the actions that the program undertakes to produce outputs. For NIOSH research programs, activities usually included conducting surveillance; investigating occupational injuries and illnesses; identifying risk and protective factors; conducting laboratory and field studies; developing and validating laboratory protocols, methods, and equipment; assessing social and economic cost and benefit of interventions; training and educating OSH professionals; and conducting exposure assessments.

Figure 3.1
Standard Elements for NIOSH Program Logic Models



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Outputs are the tangible products that are generated by the activities. Outputs include peer-reviewed journal articles, reports to Congress, recommendations, technology, patents and licenses, and training materials.

Customers are defined as the users or target of the outputs. Customers are a critical link in our logic models, as they translate outputs to outcomes. In most research programs, outcomes cannot be achieved without customers. Placing customers explicitly in the logic model helps program staff and stakeholders think through and explain how activities and outputs lead to outcomes and which population groups the program intends to serve (McLaughlin and Jordan, 2004). In the NIOSH logic models, we distinguish between two types of customers: intermediate and final.

Final customers are the end users and can be thought of as the target population of the research program. For NIOSH research programs, the final customers are generally employers and workers. Employers may need to implement changes at work sites in order to reduce injuries, illnesses, or fatalities. Similarly, workers may need to adopt recommended workplace practices or don particular workplace equipment to prevent injury. Final customers are key because, generally speaking, to achieve the end outcome, changes in the behavior of the final customers are necessary.

Intermediate customers are defined as users or customers who generally modify or transform the outputs such that they are more accessible to the final customers. One type of intermediate customer in our NIOSH logic model is a manufacturing company that takes a pilot technology that NIOSH has developed (an output) and transforms this technology into market-ready products that are more accessible to the final customers. Intermediate customers represent the reach of the program and provide the means of moving outputs beyond the domain of the program (Montague, 1998). Examples of intermediate customers include other U.S. agencies (e.g., OSHA, MSHA, EPA, Consumer Product Safety Commission [CPSC]); Congress, state or local OSH entities; international agencies; standards-setting organizations; labor, trade, and professional associations; technology developers; and tool, equipment, and material manufacturers. Although this list is not exhaustive, it is important to note that, in each of these examples, the role of the intermediate customer is to extend the reach of a particular output through some sort of modification that makes it more accessible to the final customer, whether in form (i.e., incorporation of NIOSH recommendations into an OSHA regulation) or by proximity to a particular population (i.e., training materials included in a state-based OSH training program).

Outcomes are the changes that occur and the benefits that result from the program activities and outputs. Some logic models delineate outcomes based on the time frame of when they should occur, such as short-term, mid-term, and long-term outcomes (W. K. Kellogg Foundation, 2000). Other logic models delineate outcomes based on a hierarchical system of types of outcomes, such as the seven levels of outcomes described by the targeted outcomes of programs (TOP) model (Bennett and Rockwell, 1995).

The logic models we developed with NIOSH programs distinguish between only two basic types of outcomes: intermediate and end outcomes.

End outcomes are the desired results of the program. The end outcomes for most of the NIOSH research programs are reduced work-related hazardous exposures or reductions in occupational injuries, illnesses, and fatalities within a particular disease- or injury-specific area. End outcomes describe the purpose of the program and are linked to the program's organizational mission.

Intermediate outcomes represent the customers' response to the program's outputs. Because our logic models define two types of customers—intermediate and final—the models also include two types of intermediate outcomes. The first type of intermediate outcome is based on the response of the intermediate customers and is the product that has been modified, repackaged, or customized by the intermediate customer to make it more useful or accessible to the final customer. Using our previous example of a manufacturing company as a NIOSH intermediate customer, the response of transforming the NIOSH pilot technology into market-ready products results in the intermediate outcome of market-ready technologies. These technologies are more accessible and can be directly used by the final customers. The second type of intermediate outcome is based on the final customers' actions needed to achieve the program's end outcome. For example, if a program's end outcome were reduced occupational injuries at construction sites, then an intermediate outcome would be an employer's (final customer's) adoption of new technologies at the workplace that makes the construction site safer. There are several of these types of intermediate outcomes that were common to the NIOSH research programs. These outcomes included (1) adoption of technologies;[2] (2) changes in workplace policies, practices, and procedures;[3] (3) changes in the physical environment (i.e., working environment) and organization of work; and (4) changes in knowledge, attitudes, and behavior of the final customers (i.e., employees, employers).

External factors are also included in our logic models to acknowledge aspects that are outside of the research program yet influence (either positively or negatively) the extent to which a program can achieve its end outcomes. For research programs within NIOSH, these external factors could include industry-specific legislation, major incidents and disasters (i.e., mining explosion disasters), the political environment, technological developments, and market forces. Figure 3.1 shows a series of arrows pointing upward from external factors to indicate that these factors are linked to and can influence different elements within the logic model. For example, external factors, such as access to various databases, may affect program activities, such as surveillance. On the

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2 An example of an adoption of a new technology is computer software developed by the Mining program to analyze pillar stability. This is now an industry standard and is used by MSHA and state regulatory agencies to evaluate mine permits, resulting in safer longwall operations.

3 An example of changes in workplace policies is the passage of safe patient-handling legislation in six states from 2005 to 2006. This legislation was based on patient-handling research conducted by the Traumatic Injury program.

other hand, external factors, such as government earmarks, would influence program inputs.

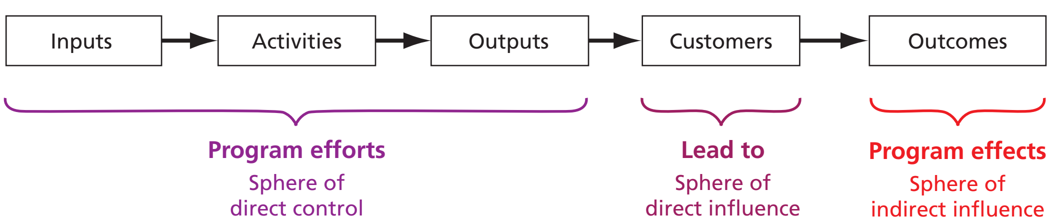
Importance of Logic Models in Demonstrating and Assessing Impacts

As described in Chapter One, there are many methodological hurdles to evaluating and demonstrating the impact of research programs. Logic models offer a means of addressing some of them. For example, the links between research activities and outcomes are often complex and long-term. Models that can articulate an observable and measurable path from inputs, activities, and outputs through a series of intermediate and end outcomes can help determine whether the research activities are more or less likely to achieve the desired societal objectives or impacts (Roessner, 2002). Logic models also help to define the domain of analysis for evaluating impact. For many research evaluations, it is difficult to move beyond assessing the merit and work of individual research projects. Logic models provide a comprehensive view of a research program—from what it does to whom it affects and the expected outcomes—that can form the basis of the evaluation. As described in Chapter Two, the Framework Committee created its evaluation flow chart from the NIOSH logic model (see Appendix A). By segmenting the NIOSH logic model into discrete, sequential program components, the Framework Committee created a flow chart that summarizes how the program evaluation should occur.

Finally, because of the multiple contributors to any given end outcome, the logic model helps define the program's sphere of influence—i.e., for what the program can take credit and be held responsible. Figure 3.2 illustrates how the logic model distinguishes program efforts from program effects and thus defines where a program is likely to have direct control, direct influence, and indirect influence.

The program has direct control over its inputs, activities, and outputs (except for the influence of external factors). Once the program transfers its outputs to its customers, the program may have less control but may influence how its customers use its

Figure 3.2
Logic Models Distinguish Program Efforts from Effects



SOURCE: Pahl et al. (2003).

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outputs. At the outcome level, a program has indirect influence at best, but it continues to bear responsibility for contributing to its intended outcomes.

Linking Program Operations to Program Strategy

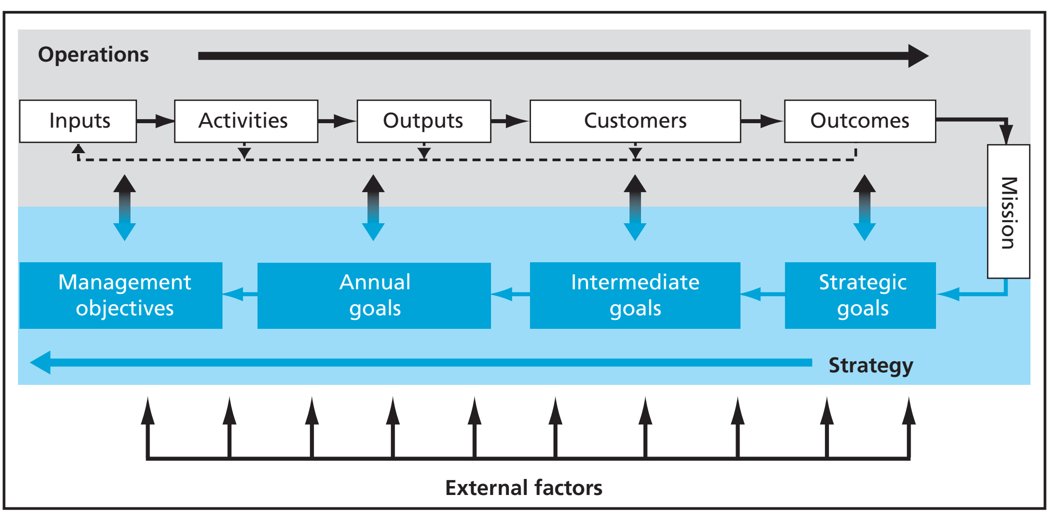
One useful feature of this model is the link between standard elements (i.e., inputs, activities, outputs, and outcomes) and the mission and goals of the program (Figure 3.3).

We refer to the standard elements as depicting the *program operations* and the program goals (i.e., strategic, intermediate, and annual) as depicting the *program strategy*. Note that *program operations* flow from left to right and include the standard logic model elements described in the previous section.

In contrast, *program strategy* flows from right to left and includes the following: Strategic goals (such as a reduction in the incidence of a particular type of injury) derive from the program's mission; intermediate goals (such as an increase in public knowledge regarding proper safety measures) derive from strategic goals; annual goals (such as the conduct of research on proper safety measures and the publication of safety reports) derive from intermediate goals; and management objectives (such as those regarding the efficient use of NIOSH resources) derive from preceding goals.

Connecting these two fundamental components of a research program—program operations and program strategy via the program mission—provides an internal check that what the program is doing and the goals it has defined for itself are vertically aligned. This alignment allows the logic model to be used as a program management

Figure 3.3
Logic Model Links Operations to Strategy



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tool because it provides structure and guidance for how a program should define its strategic, intermediate, and annual goals. Generally speaking, strategic goals should relate to the program's contribution to end outcomes; intermediate goals should relate to customers and intermediate outcomes, such as those involving changes in policies, behavior, or the work environment; annual goals should relate to program activities and outputs; and management objectives should relate to program inputs and activities. We refer to this linking of program operations to program strategy as the logic model horseshoe template and use this template in the logic models we developed (Greenfield, Williams, and Eiseman, 2006).

Generating the Information for the Logic Model

Filling in the logic models with specific information about a research program requires detailed information about research program operations. Surprisingly, this information is not often readily available and is best generated through discussions with program personnel. Because no single individual can provide all of the information necessary to explicate the complete program-operation path, meetings with key program personnel, including program managers, coordinators, and staff scientists, are necessary to build a logic model. Next is a set of discussion points that we used in meetings with NIOSH program staff to facilitate the development of the logic model. The discussion points were intended to elicit information about program operations and strategy and to closely parallel the structure of the stylized logic model shown in Figures 3.1 and 3.3. In abbreviated form, we addressed the following questions:

- What is your program trying to achieve and why?
- Who are your customers, partners, and other stakeholders?
- What types of infrastructure-support activities (e.g., planning and funding processes, laboratories) does your program undertake?
- What other inputs are used to generate activities?
- What does the program do (e.g., conducts surveillance, undertakes or funds research, develops and evaluates interventions)?
- Do you work with partners? If so, who are they and how do you work with them?
- What does the program produce (e.g., papers, methods, technologies, training or educational materials, workshops, programs)?
- How are the outputs disseminated or transferred to others?
- How (and by whom) are the outputs used and for what purposes?
- What are the intended outcomes of your activities?
- What are the program's boundaries and niche?
- What external factors affect your efforts?

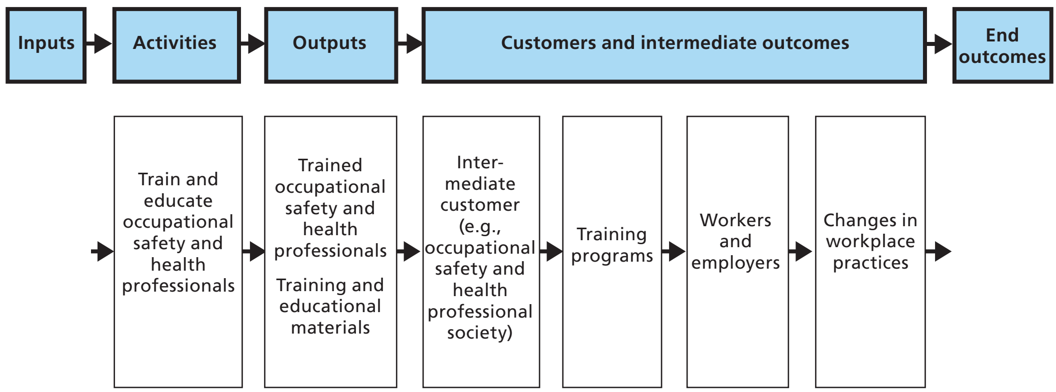
The information gathered from the discussions was used to develop an initial draft of the logic model. The first step was to categorize the information gathered from discussion with program staff within the correct logic model element. In most instances, this categorization was fairly straightforward. However, in other cases, contextual details were critical in determining the correct categorization. For example, distinguishing an output from an outcome hinges on the involvement of customers, so understanding who is doing what at each stage of the logic model is critical. Once the text was categorized correctly, the next step was determining which information needed to be featured in the logic model. In general, the information collected from discussions with program personnel described individual projects within a program. However, for the logic model, the research program—not a project—was the appropriate unit of analysis. Thus, to represent the totality of the research program, we combined similar inputs, activities, outputs, and outcomes. Representing research programs as logic models depended on using concise terminology while maintaining as much detail as possible to relay the complexity of a program's operations. We paid particular attention to the language used to describe each element of the logic model. For activities, we consistently used verbs to describe what was done (e.g., *develop guidance documents*, *develop and validate model investigation protocols and analytic methods*), and, for outputs, we consistently used nouns to describe what was produced (e.g., *guidance documents*, *model protocols*, *new analytic methods*). Since many of the types of inputs, activities, outputs, customers, and outcomes are similar between the various NIOSH programs, we maintained as much consistency as possible in the terminology used for each program's logic model.

One of the more rigorous aspects of the logic models was the attention we paid to connecting the information within the boxes across each of the logic model elements. For example, we made sure that each output was linked to one or several activities, and each intermediate outcome was linked back to specific outputs that a program's customers used or adopted. An example of this linking is shown in Figure 3.4.

The program activity *train and educate OSH professionals* results in the outputs of *trained OSH professionals* and *training and educational materials*. These training and educational materials may be transferred to intermediate customers who use these materials to develop training programs, an intermediate outcome of the research program. Final customers, such as employers and employees, may participate in these training programs, leading to changes in workplace practices, another category of intermediate outcomes. Over time, these changes in workplace practices could contribute to a reduction in occupational injuries, the end outcome.

Program staff provided input on each iteration of the logic model, specifically on its accuracy, content, structure, and flow. It was during these iterations that we developed some of the nuances that are present in the final logic models. For example, the difference between resources used to support activities and resources used to determine activities to be undertaken was considered to be an important distinction

Figure 3.4
Linking Elements Within Logic Model Boxes



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among NIOSH research programs and thus *production* and *planning* resources became a standard feature of the logic models we generated. The last stage of our logic model development involved adding details to the model that established some distinctive elements of each of the research programs, such as the depiction of a program's relationship with its partners, and the incorporation of information about programs with both research and service components. Working with program staff, the logic model was determined to be complete when there was general consensus among all involved about the accuracy of the logic model's representation of the research program. In the next section, we discuss some of the nonstandard elements of the logic models that we developed with NIOSH programs.

Approaches for Addressing Research Complexity in the Logic Models

Despite the standard structure (i.e., boxes and arrows) and elements (i.e., inputs, activities, outputs, and outcomes) in logic models, there are a number of ways to customize these models so that details that are critical to illustrating program operations can be included. The use of various formatting tools, such as italics, bolded text, dashed lines, and colors, can be used to indicate subtle differences. However, finding the balance between the simplicity of the basic flow of the logic model and including important contextual features is challenging. A logic model is, by necessity, an abstraction that omits detail for the sake of clarity of representation. The trade-off between detailed accuracy and clarity of presentation varies according to context and purpose. In developing logic models with NIOSH programs, clearly depicting the paths to outcomes was the priority. Thus, we maintained the linear flow of the logic model, using feedback loops and other divergent pathways sparingly. Because the programs were undergoing external review, we favored a more simplified model that would enable a reviewer to look at the logic model and see the path of how a program achieves its end outcomes. Although we recognized that there might be exceptions, the expert reviewers' ability to assess impact depended, in part, on their understanding of how the program operated. We did not want to jeopardize the clarity of the model by including too many details. Moreover, because these logic models were included as part of the evidence package, many of the details not shown in the models were explained in different sections of the package.

In developing logic models with the different research programs, we encountered a number of complexities that necessitated varying the logic models. Two of the most significant ones were representing partnerships in logic models and describing research programs that did more than just research. Both of these conditions are conceptually complex and common to many research programs. In the following sections, we discuss some of the challenges we faced in addressing these issues and the approaches we used to resolve them.

Representing the Role of Partners in Logic Models: The Mining and Construction Research Programs

NIOSH programs collaborate or partner with many other federal, state, local, and private organizations, including federal agencies (e.g., OSHA, Bureau of Labor Statistics [BLS], CDC); state health and labor departments; standards-development organizations (e.g., International Organization for Standardization [ISO], American National Standards Institute [ANSI]); labor, trade, and professional associations; and technology developers and manufacturers. Thus, depicting the contribution of NIOSH partners in achieving outcomes was an important element to add to the logic models.

Representing partners in the logic models was complicated by trying to determine how they differed from customers, which were already present in the logic models. For many of the programs with which we worked, partners primarily played a supportive role, enabling the research programs to carry out activities or produce outputs. Thus, we defined *partners* as those who work with research programs to conduct activities or enable outputs, whereas *customers* are defined as the users or targets of the outputs. Note that these definitions are not mutually exclusive, and the same entity that serves as a partner in one context may serve as a customer in another. For example, state health and labor departments may work with NIOSH to produce training and education programs and can therefore be described as partners; however, they can also use these outputs as customers.

To represent partners and the supportive role (rather than a more direct or active role), we used a shaded box to encompass the logic model elements in which partners played a key role. At the bottom of the box, we listed the partners that the research programs described for us. Although this represented our general strategy for depicting partners, there was some variation in which boxes were encompassed and which groups or entities were included as partners. Clearly, the full complexity of partners and their relationship with NIOSH programs is not accounted for by simply adding another box to the logic model. However, this additional component (i.e., the green shaded box) was used to underscore the importance of partnership in the program's path to achieving end outcomes.

In the following sections, we describe logic models for two of the NIOSH programs we assisted: Construction and Mining. The role of partners in these two research programs is different, and we discuss how we illustrated these differences in the logic models.

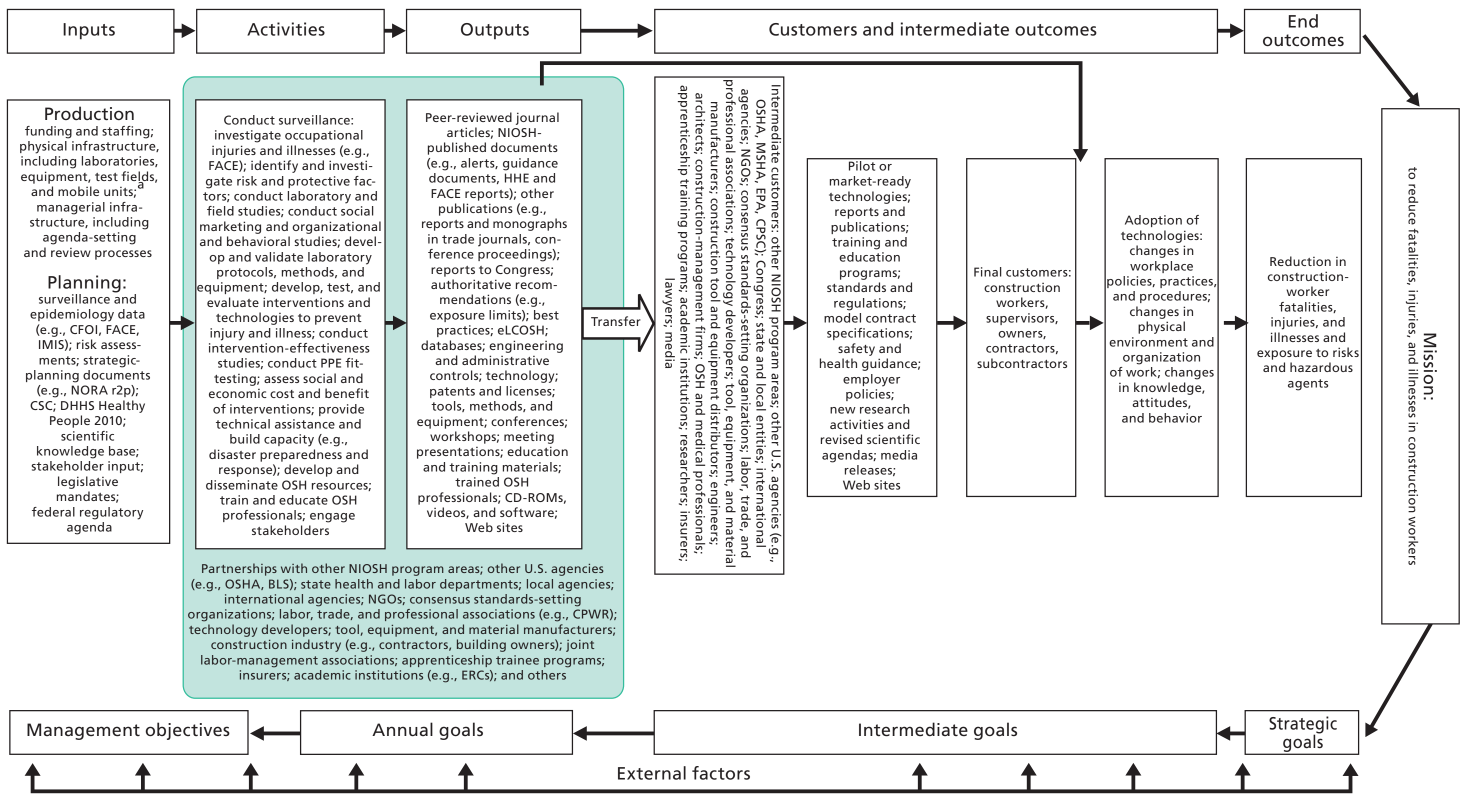
The Construction Program. The Construction program was created in 1990 by Congress to "develop a comprehensive prevention program directed at health problems affecting construction workers by expanding existing NIOSH activities in areas of surveillance, research and intervention" (NIOSH, 2007a). The program is made up of three main components: NIOSH-wide intramural research and surveillance programs; a large national Construction Center cooperative agreement; and investigator-initiated extramural research. Partnerships are integral to the Construction program. Research with its partners sometimes includes in-kind contributions that help to leverage NIOSH research dollars (NIOSH, 2007a). Partners can also add expertise or specialized experience to the research team. The Construction program has partnerships with several key players involved with construction issues, including OSHA; the construction industry; labor, trade, and professional organizations (e.g., United Brotherhood of Carpenters and Joiners of America [UBC]; Laborers' International Union of North America [LIUNA]); and academic institutions (e.g., NIOSH Education and Research Centers [ERCs]).

One partnership in particular is integral to the Construction program—its partnership with the Center for Construction Research and Training, formerly known as the Center to Protect Workers' Rights (CPWR), a research center established by the Building and Construction Trades Department of the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO) that includes a consortium of academic and industry research organizations. Since 1996, the CPWR has been awarded the national Construction Center cooperative agreement, which is intended to promote dialogue and collaboration among researchers. As a partner, the Construction Center provides important linkages to the construction community and focuses and coordinates research that is often more applied than NIOSH intramural research.

The Construction program uses the term *partners* to refer to stakeholder groups that collaborate with it on program activities. In the logic model we developed with the Construction program, we depict its partnerships as enabling both activities and outputs by drawing the shaded partnership box around the activities and outputs boxes (Figure 3.5).

To denote the dual role of partners as customers, many of the entities listed as partners are also in the "Intermediate customers" box. Having partners that also were intermediate customers was a common strategic decision by many of the research pro-

Figure 3.5
Logic Model for the NIOSH Construction Program



SOURCE: NIOSH (2007).

NOTE: CFOI = Census of Fatal Occupational Injuries. FACE = Fatality Assessment and Control Evaluation. IMIS = Integrated Management Information System. r2p = research to practice. CSC = Construction Steering Committee. PPE = personal protective equipment. eLCOSH = Electronic Library of Construction Occupational Safety and Health. NGO = nongovernmental organization.

[a] NIOSH laboratories and other facilities used to conduct research through grants, cooperative agreements, and contracts.

RAND *MG809-3.5*

grams with which we worked. Involving intermediate customers early on as partners helped to ensure that the outputs that customers received were relevant and increased the likelihood that customers would use the outputs resulting in the expected program outcomes.

The Mining Program. The Mining program partnerships facilitate advances in the safety and health of U.S. mine workers through input from customers and stakeholder groups to help set research priorities, in-kind contributions (such as equipment and test mine sites) to extend research dollars, and expertise or specialized experience to supplement the research team. The Mining program groups its partnerships into three categories: those with (1) important customers and stakeholders to identify research needs and transfer research findings, (2) manufacturers and mining companies to conduct research and develop products, and (3) organizations to exchange safety and health information and technology and to conduct research in areas of mutual benefit. These partnerships enhance the Mining program and also allow for faster transfer of knowledge and products to the mining industry.

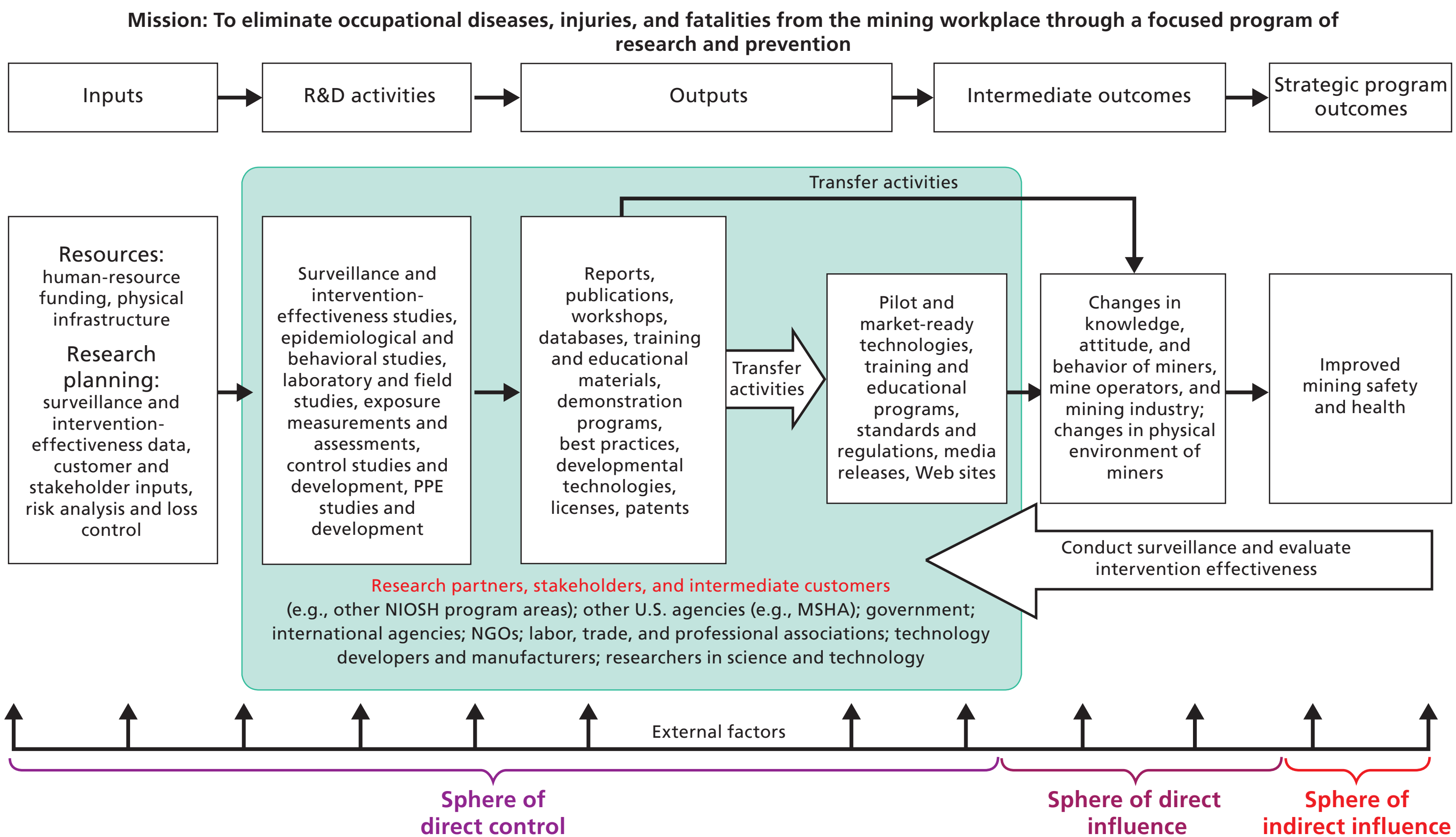
In comparison with the Construction program, the Mining program has a more complicated relationship with its partners. The Mining program works very closely with a broad spectrum of members of the mining community, and, similar to Construction, many of the partners are also stakeholders and intermediate customers. However, Mining differs in that there is considerable overlap in the ways in which these different groups contribute to outcomes. In particular, the Mining program considers its relationships with partners, stakeholders, and intermediate customers integral to the transfer of their research findings. Therefore, partners, stakeholders, and customers were grouped together in a shaded box encompassing activities, outputs, transfer activities, and the first intermediate outcomes box (Figure 3.6). The shaded box lists some of the primary partners, stakeholders, and intermediate customers of the NIOSH Mining program.

The Mining program logic model suggests a close relationship with partners, stakeholders, and customers that essentially extends the sphere of direct control. In contrast to the Construction program, in which there is a clear transfer of outputs to intermediate customers, there is no transfer arrow to intermediate or final customers in the Mining Program logic model. The Mining program engages with research partners, stakeholders, and customers through to intermediate outcomes and, consequently, assumes greater responsibility for achieving intermediate outcomes. This is illustrated in Figure 3.6, in which the sphere of direct control in the Mining research program ranges from inputs to the first "Intermediate outcomes" box.

Describing Multifaceted Research Programs: The Health Hazard Evaluation and Personal Protective Technology Programs

Two NIOSH programs presented the challenge of how to represent those that do more than just research. The HHE program has a service component of responding to cus-

Figure 3.6
Logic Model for the NIOSH Mining Program



SOURCE: NIOSH (undated [b]).
NOTE: The mining program created its logic model, so the headings and overall structure of this logic model differ slightly from the others that we illustrate.
RAND *MG809-3.6*

tomer requests for hazard evaluations. The PPT program has a component that is responsible for certifying all respirators used in the United States. In both cases, additional details were included in the logic models to create a more accurate depiction of the programs and how they achieve their outcomes.

The Health Hazard Evaluation Program. The HHE program is designed to respond to requests for field investigations of potential health hazards in the workplace. These field investigations are called health hazard evaluations, or HHEs. However, there is also a research component to this program, as some of these requests can present opportunities for further investigations. Figure 3.7 is the logic model we developed in collaboration with the HHE program.

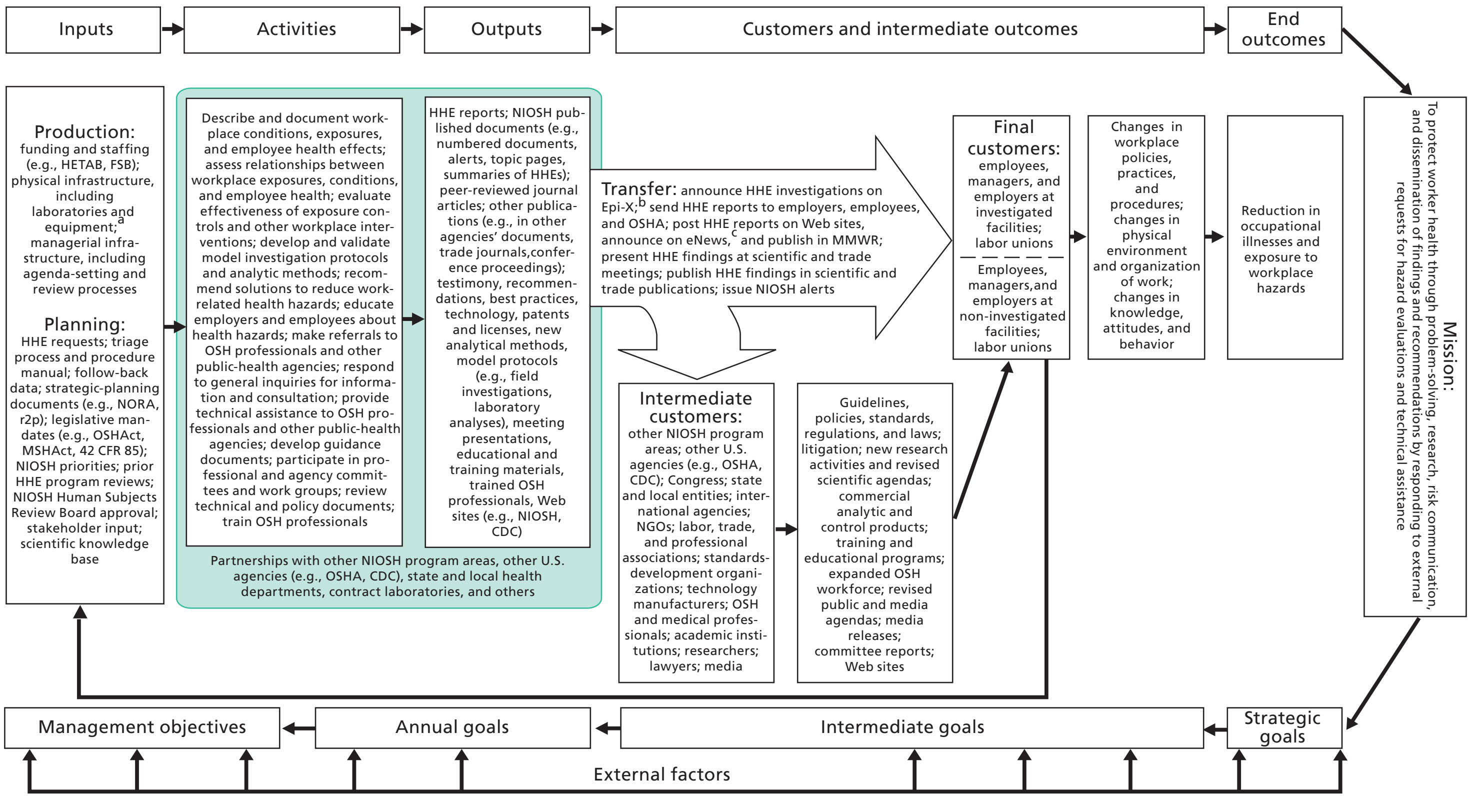
The service component of the HHE program is represented in the path on which the program's outputs are transferred directly to its final customers: (1) employees, managers, and employers at investigated and other facilities and (2) labor unions. In this case, a feedback loop from the final customers to the inputs is used to indicate that customer feedback from these investigations informs production inputs as well as planning inputs for future program activities. The research component of the HHE program is represented in the path on which the outputs are transferred to intermediate customers who modify and repackage the outputs so they are more accessible to final customers.

The HHE program logic model also illustrates another feature that we incorporated into some of our logic models: the expanded "Transfer" arrow. The Framework Committee considered transfer activities to be distinct from research activities. For programs, such as HHE, that used different types of transfer mechanisms to relay its outputs to the appropriate customers, these mechanisms are specifically detailed in the "Transfer" arrow in the logic model.

The Personal Protective Technology Program. The mission of the PPT program is to prevent work-related injury, illness, and death by advancing the state of knowledge and application of personal protective technologies. Although the PPT program was not established until 2005, NIOSH had initiated a research program on personal protective technologies as early as 1973. The PPT program fulfills its mission through three major areas: (1) research, (2) participation in standards setting and policymaking, and (3) respirator certification (NRC, 2008). The complexity introduced by these three distinct areas is evident in the logic model shown in Figure 3.8.

The respiratory protection research conducted by the PPT program and the NIOSH respirator-certification program follow two parallel paths within the PPT program. Both paths are guided by the same inputs, but the congressional mandate to conduct respirator certification dictates that the emphasis on the respective inputs be different for each path (NIOSH, 2007b). Respiratory research and the respirator-certification program each have their own set of activities, outputs, intermediate customers, and intermediate outcomes. There are some interactions between the research path and the respirator-certification path, indicated by arrows connecting the two paths. Some of

Figure 3.7
Logic Model for the NIOSH Health Hazard Evaluation Program



SOURCE: NIOSH (undated [c]).
NOTE: HETAB = Hazard Evaluations and Technical Assistance Branch. FSB = Field Studies Branch. MMWR = *Morbidity and Mortality Weekly Report*.
[a] NIOSH laboratories and other facilities accessed through contracts.
[b] Epi-X is the Epidemic Information Exchange, CDC's secure communication network for public-health professionals.
[c] eNews is NIOSH's monthly newsletter.
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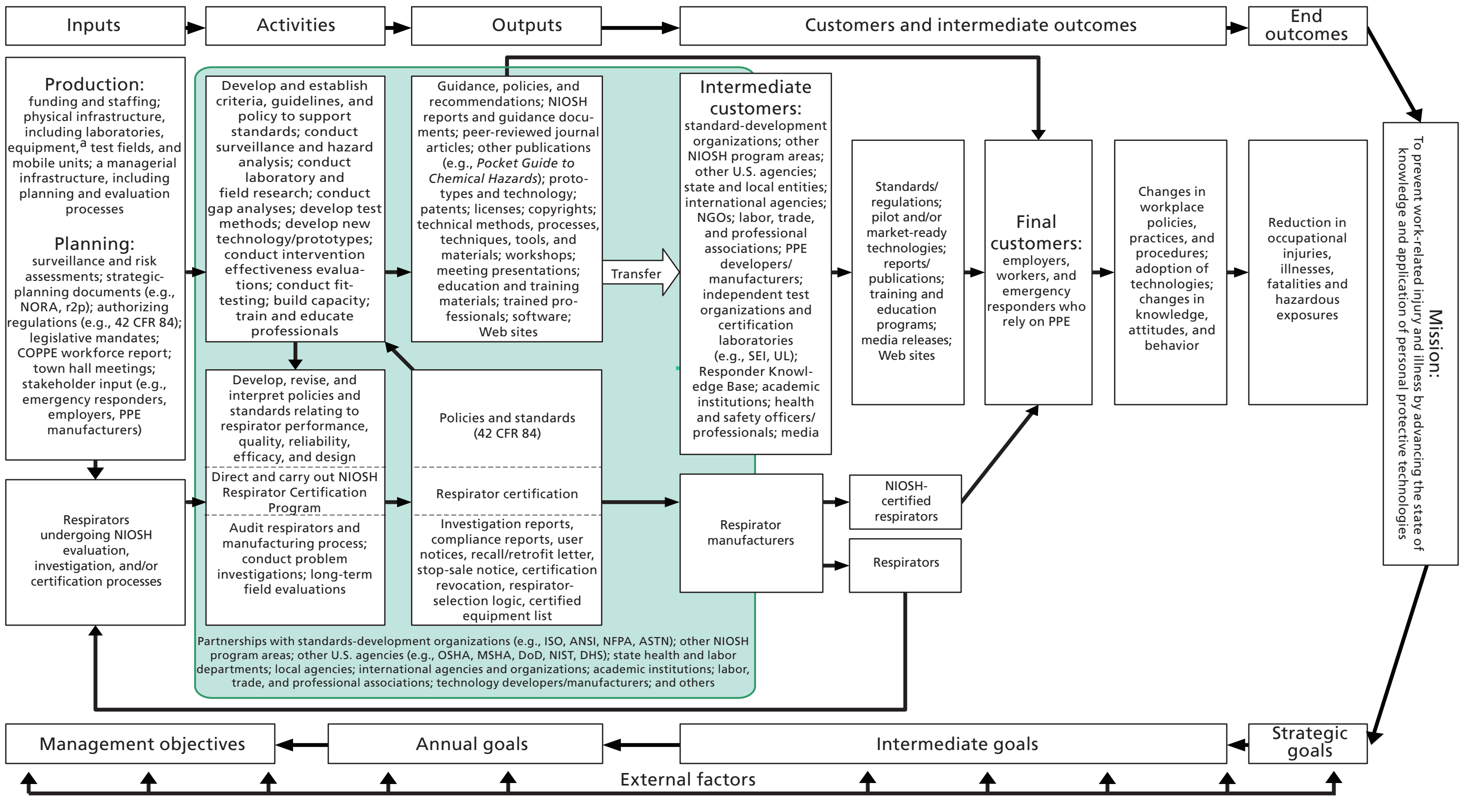
Figure 3.8
Logic Model for the NIOSH Personal Protective Technology Program



SOURCE: NIOSH (2007).
NOTE: COPPE = Committee on Personal Protective Equipment. NFPA = National Fire Protection Association. ASTM = ASTM International (formerly, the American Society for Testing and Materials). DoD = U.S. Department of Defense. NIST = National Institute of Standards and Technology. SEI = Software Engineering Institute. UL = Underwriters Laboratories.
[a] NIOSH laboratories and other facilities accessed through contracts, cooperative agreements, and contracts.

RAND *MG809-3.8*

the research activities feed into the activities of the respirator-certification program. For example, the research activity to "develop and establish criteria, guidelines, and policy to support standards" directly feeds into the respirator-certification program activity of "develop, revise, and interpret policies and standards relating to respirator performance, quality, reliability, efficacy, and design." Likewise, some of the outputs of the respirator-certification program may generate activities for the research program. For example, investigation reports generated through the respirator-certification program may drive intervention-effectiveness evaluations by PPT researchers.

Both paths converge at the level of final customers—employers, workers, and emergency responders who rely on personal protective equipment. In addition to the intermediate outcomes from the research path (i.e., standards and regulations, pilot or market-ready technologies, reports and publications, training and educational programs, media releases, and Web sites) and the respirator-certification program (i.e., certified respirators), some of the respirator-research outputs are delivered directly to the final customers (e.g., *Pocket Guide to Chemical Hazards* [NIOSH, undated(d)]) as indicated by the arrow connecting the research outputs to the final customer. Another unique element of the PPT program's logic model is the feedback into inputs from respirator tests that fail the NIOSH certification process. Respirators that have not received NIOSH certification must go back through the certification process before they can be used in the workplace.

The partnership box in the PPT program logic model is drawn to indicate that effective partnerships are crucial to the success of the PPT program. Individuals or groups that form partnerships with the PPT program are actively involved in the program's activities and outputs and sometimes even assist in the transfer of outputs to intermediate customers. Therefore, the shaded partnership box is drawn to encompass activities, outputs, and transfer to intermediate customers.

Of all of the logic models we developed for the various NIOSH programs, the PPT logic model is the most complex. Not only does it depict the dual paths for the respirator research program and the respirator-certification program, but it also depicts a more complex interaction with its partners than the Construction and HHE programs have. It also makes use of several arrows to show the interactions between the two paths, a feedback arrow that brings some of the intermediate outcomes back into the inputs, and a direct link from PPT program outputs to the final customer.

Concluding Thoughts

Creating program logic models was the first step in preparing NIOSH research programs for external review and helped to establish the research program (rather than projects) as the unit of analysis. In addition, the logic models were used to orient the research programs to focus on outcomes rather than outputs. In the next chapter, we discuss how the logic models were used to prepare outcome worksheets, a tool for data collection and for tracing how specific research activities led to end outcomes.

CHAPTER FOUR

The Outcome Worksheet

The National Academies' framework document, described in Chapter Two, provided guidance on the types of data the NIOSH research programs needed to provide in order to demonstrate impact. For example, to assess the outputs of research programs, the framework document listed peer-reviewed publications by program staff; peer-reviewed publications by external researchers funded by NIOSH; NIOSH reports in the research programs; sponsored conferences and workshops; databases; recommendations; tools, methods, or technologies; and patents. However, findings from phase I of our study indicated that most programs that underwent external review found that some analysis of the information was needed in order to make sense of the data. According to program managers in other agencies whose programs had undergone reviews, simply handing over reams of documents that represent evidence was not perceived to be especially helpful to either the reviewers or the program being reviewed. Moreover, they felt that programs should carefully consider which specific pieces of information are needed to demonstrate impact and how to convey the context that will give meaning to the data.

The guidance we provided to NIOSH research programs for helping to determine the pieces of evidence, as well as the broader context, is based on the historical tracing method. This method traces chronologically a series of interrelated events either going forward from the research of interest to downstream outcomes or working backward from an outcome along a path that is expected to lead to precursor research (Ruegg and Jordan, 2007). In conjunction with the logic models discussed in Chapter Three, we adapted this methodology to help NIOSH research programs describe the causal link between their activities in the laboratories and larger societal outcomes. An important tool that supported the use of this method was the outcome worksheet. The outcome worksheet was primarily designed as a practical tool to help NIOSH researchers think through the causal linkages between specific outcomes and research activities, determine the data needed to provide evidence of impact, and provide an organizational structure for the evidence.

In this chapter, we briefly review the evolution of historical tracing and its role in evaluating and assessing R&D impact. We also describe the development of the outcome worksheets and how they were used to assist NIOSH research programs in tracing specific linkages between their research activities and end outcomes.

The Evolution of Historical Tracing

One of the earliest examples of historical tracing was Project Hindsight. DoD conducted Project Hindsight during the early 1960s to develop an understanding of the costs and benefits of supporting basic versus applied research (Sherwin and Isenson, 1967). Project Hindsight focused on 20 major weapon systems supported by DoD and traced the development of each backward 20 years to identify the key research outputs that contributed to each system's realization. The findings of this study suggested that the returns to DoD for its investment in basic research over a 15- to 20-year time frame were small in comparison with other categories of research (Kreilkamp, 1971). In considering the payoff of basic research over a longer time frame, the study indicated that basic research had created value and noted the contributions of atomic and nuclear physics as an example of this. Officials of the U.S. Office of Science and Technology Policy (OSTP) and the NSF objected strongly to Project Hindsight's methodology, the use of research events to determine the cost-effectiveness of basic research, and, in particular, to its short time frame (20 years).

Project Hindsight was followed by the Technology in Retrospect and Critical Events in Science (TRACES) study and was sponsored by the NSF in 1967 (IIT Research Institute, 1968). In contrast to Project Hindsight, the goal of this study was to provide more-detailed information on the role of various mechanisms, institutions, and types of R&D activity required for successful technological innovation. The TRACES study used essentially the same methodology as Hindsight, but with a longer time frame. The results indicated that basic research had made a substantial contribution to innovation, thus highlighting the importance of the time frame selected for these sorts of studies.

In a more recent version of the TRACES study, the National Cancer Institute initiated an assessment to determine whether there were certain research settings or support mechanisms that were more effective in bringing about important advances in cancer research (Narin, 1989). The approach taken was analogous in concept to the initial TRACES study, with the addition of citation analyses to provide an independent measure of the impact of the papers associated with key events.

The historical-tracing approach has been used in a widely adopted format known as a *standard accomplishments book* (Kostoff, 1994). Standard accomplishments books describe scientific accomplishments in sufficient detail for the reader to understand the science that was accomplished and have some idea of the potential importance of the research to the organizational mission, technology, and, perhaps, the commercial sectors. Accomplishments books are not intended to be all-inclusive, nor do they include quantitative estimates of impact. The accomplishments are drawn from the different disciplines funded by the organization and are meant to be portrayed as representative of the breadth of activity (Kostoff, 1997). The Office of Health and Environmental Research (OHER) at the DOE published an accomplishments book that described the 40-year history of OHER and presented selected accomplishments in different research areas that allowed the impacts and benefits of the research to be tracked through time (Kostoff, 1997).

As the methodology has evolved, there has been less emphasis on using it to determine the cost-effectiveness of research and more emphasis on using it to describe accomplishments and illustrate how investments, research activities, and outputs contribute to outcomes that benefit the public. For example, SRI International conducted case studies for the NSF about the evolution of six major engineering innovations: the Internet, magnetic resonance imaging (MRI), reaction injection molding (RIM), computer-aided design (CAD) applied to electron circuits, and optical fiber for telecommunication and analog cellular phones (Roessner, 1998; Roessner et al., 1997). The studies documented the consequences of the NSF's support of research, education, infrastructure, supporting technology, organizational leadership, and facilitation of technical communication and interaction for the conception, emergence, and commercial success of each innovation. The case studies provided detail about the processes by which various modes of research support contributed to the realization, over time, of a variety of valued outcomes and impacts.

Research-value mapping (RVM) is another method for tracing outcomes to research activities (Bozeman and Roessner, 1995). However, RVM represents a significant departure from earlier attempts to tell a story about the chronology and events contained within the boundaries of a research project. The RVM approach begins with carefully specified and testable models of causation, as well as a scheme for linking the individual cases. This yields particularistic data, such as those derived from a particular case, and generalizable data, which come from the quantification of elements across cases (Bozeman and Kingsley, 1997). Despite its value as one of the few approaches to historical tracing that uses both qualitative and quantitative data, it is inherently resource-intensive, requiring a sufficient number of cases to permit quantitative analysis and application of inferential statistics.

For the most part, historical tracing relies on qualitative data, including interviews with those involved in research activities, records and descriptions of research activities, and input from stakeholders and users of the products generated from the research. It identifies critical antecedent development, such as the development of a particular technology, or publishing of an influential report that was instrumental to achieving the outcome. Key events, people, documents, and organizations are noted and the linkages among them established to build a causal chain that, in the end, demonstrates causal contribution. Critical questions that can be addressed by this method include the following:

- How have the ideas that emerged from this research influenced subsequent thinking and discovery?
- What is or has been the path from innovation to output to outcome and impact?
- What were the key factors influencing this path?

In drawing on the historical tracing method, we augmented it with the program logic model to increase the transparency of the plausible causal linkages between research activities and outcomes. Thus, the significance of key outputs is based on their contribution to outcomes, which is supported by documentation from customers and stakeholders. Tracing the specific impact pathway between research activities and outcomes also relied on identifying and gathering the appropriate data to substantiate the causal linkages in the path to end outcomes. To achieve this, we developed outcome worksheets based on the logic model.

Developing Outcome Worksheets: Building from Logic Models

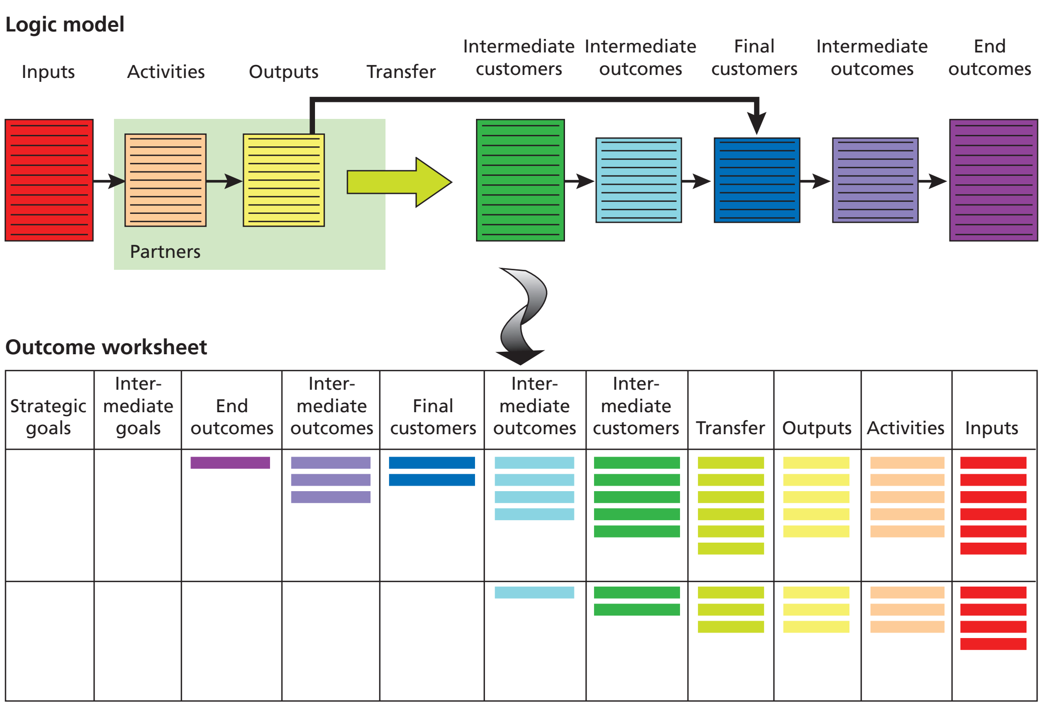
The first step in developing the outcome worksheet is deciding whether to trace the research path forward (i.e., from research activities to outcomes) or backward. Forward tracing can capture a complete view of a research project's or program's effects, and, because the path leads from the research, the connection to the research is ensured. An example of the use of forward tracing is a recent study that used the Buxton-Hanney payback model to trace the returns from arthritis research funded by the Arthritis Research Campaign to its outcomes (Wooding et al., 2004). Case studies of 16 research grants were conducted and written up as a narrative organized according to the structure provided by the payback framework. Cross-case analysis was conducted to assess the extent to which different types of funding support might prevent or promote the successful translation of research. As such, forward-tracing studies may be of interest to parties investing in or undertaking research (Wooding et al., 2005).

Backward tracing usually focuses on a single outcome of importance and follows the trail back through those developments that were critical in reaching the identified outcome. One implication of backward tracing is that it highlights activities that led to anticipated outcomes and may not capture the broader range of outcomes that forward tracing may lead to or may select only the most positive cases of outcomes. However, the National Academies' reviews focused on impact, so outcomes were the natural starting point, followed by customers, transfer activities, outputs, research activities, and, finally, inputs. Not only did this backward tracing reinforce the emphasis on outcomes, it also oriented researchers to focus on a collective body of research rather than on individual research projects. Outcomes typically flow from a collective body of research activities that may occur over several years, not an individual research project. With rare exceptions, individual research projects will most likely lead to outputs (such as journal articles, recommendations, and findings) but seldom result in intermediate outcomes (such as changes in practice by an employer or employee). However, collectively, a body of research conducted during a specific time frame is likely to lead to significant outcomes.

To prompt program staff to begin to think backward from outcomes to earlier stages, we created a graphic to illustrate this reversal. Figure 4.1 illustrates how the logic model path, beginning with inputs, was reversed (i.e., beginning with end outcomes) to create the outcome worksheet.

The logic model begins with the "Inputs" box at the left end and ends with the "End outcomes" box in purple. The outcome worksheet (shown in the lower half of Figure 4.1) reverses the order of the logic model elements, with the end outcomes at the left end and the inputs at the right. This reversal of order moves beyond the program theory articulated in the logic model and essentially places the burden on research programs to trace backward how specific outcomes were generated from research activities. The colored bars within each of the columns represent the text that describes a particular logic model element (e.g., inputs, activities). Because our purpose in creating the outcome worksheet was to help the research programs think through the impact

Figure 4.1
Moving from the Logic Model to the Outcome Worksheet



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pathway—or path to outcomes—in as much detail as possible, each column corresponds to an element of the logic model, including the transfer arrow. For an impact evaluation, it is important to explicate the role of intermediaries in the uptake, adoption, and use of research outputs (Cooksey, 2006). Thus, we distinguished between the two categories of customers (intermediate and final) as well as the corresponding categories of outcomes (intermediate and end). The "Intermediate outcomes" column with the purple bars corresponds to the response and actions taken by final customers, and the column with light-blue bars corresponds to the response and actions taken by the intermediate customers. Despite the redundancy in terminology, this detailed parsing of information ensured transparency of the linkages between information across the columns. The inclusion of strategic and intermediate goals in the outcome worksheet is based on guidance from the framework document, which recommended that the ECs evaluate the research program goals and objectives and provide a qualitative assessment of the relevance of the program's goals, objectives, and strategies in relation to its major challenges. Because our logic model template (Figure 3.3 in Chapter Three) links and aligns program operations with program strategy, inclusion of the goals in the outcome worksheet reinforced the supportive relationship between program operations (i.e., inputs, activities, outputs, and outcomes) and program goals.

An example of the type of information included in the outcome worksheet can be found in the HHE program. In this program, facilities that are being investigated by the HHE research program are one category of final customers, and the names of these facilities would be listed in the column labeled "Final customers." Similarly, in the "Intermediate outcomes" column to the left, specific descriptions of adoption of technologies; changes in workplace policies, practices, and procedures; or changes in the physical environment and organization of work linked to these final customers would be appropriate information to include in this column. An example of an intermediate outcome from the Hearing Loss Prevention program is the "manufacture of plastic coated flight bars for continuous mining machines" by Joy Mining Machinery, a continuous-miner manufacturer. The manufacture of the coated flight bars is based on research activities in the Hearing Loss Prevention program to develop and, ultimately, produce a chain conveyor with coated flights as a noise control.

Note that, in Figure 4.1, there is one bar underneath the "End outcomes" column and multiple bars in the other columns, with the greatest number of bars in the "Inputs" column. Pictorially, this reinforces an earlier point—namely, that an end outcome will often derive from a body of research rather than from a single research activity. For example, an end outcome of a 10-percent reduction in construction workers' asbestos exposure will likely result from multiple research activities, such as field studies to assess the prevalence of asbestos exposure, intervention studies to document the most cost-effective ways to minimize exposure, and perhaps population studies to document construction workers who are at higher risk for asbestos exposure. Each of these research activities are likely to lead to several outputs that are transferred to different customers, leading to intermediate outcomes that serve as precursors to the end outcome.

Gathering Data for the Outcome Worksheet

We asked program managers to identify the most-significant outcomes that occurred during the period under review. The program managers shared information with the program researchers. The number of outcomes varied across programs. In the Hearing Loss Prevention program, 44 outcomes were initially identified across 10 major research areas, whereas in the Traumatic Injury research program, approximately 23 outcomes were identified. To conform to the guidance from the framework document, we asked the research programs to group the outcomes by strategic goals. As described in Chapter Three, our logic model template shows that end outcomes and strategic goals should be mutually supportive. For example, one of the strategic goals of the Traumatic Injury program is to reduce occupational injuries and fatalities in Alaska. End outcomes that support the achievement of that goal include reducing occupational injuries and fatalities in commercial fishing, helicopter logging operations, and Alaska aviation. This connection between the program's strategic goals and their outcomes was an important structural feature that created coherence within the research program description.

Identifying outcomes was the starting point for gathering evidence to demonstrate impacts. After listing the intermediate or end outcomes, we asked programs to fill in the box immediately to the right. In the case of end outcomes, the next box contains the intermediate outcomes. In cases in which programs could report only intermediate outcomes, the next box contains customers (final or intermediate). For the most part, the research programs did not complete the outcome worksheet in a linear fashion but rather filled in the cells with the most-accessible information first. Not surprisingly, linking research activities to outputs and identifying the research activities and outputs that could be associated with the significant outcomes were fairly straightforward. However, determining the path of how the outputs contributed or led to an outcome required more time and effort.

Each program employed its own strategy for gathering data to complete the outcome worksheets. These approaches included reviewing their own transfer activities in reaching intermediate and final customers, directly contacting intermediate customers (i.e., industry, trade associations, other federal agencies, state and local OSH agencies) to find out how specific outputs had been used; contacting partners to find out whether they were aware of and could cite changes in the workplace based on program work; following up with individuals or organizations that requested information from the research program; using search-engine tools (i.e., Google® search, LexisNexis®, Public

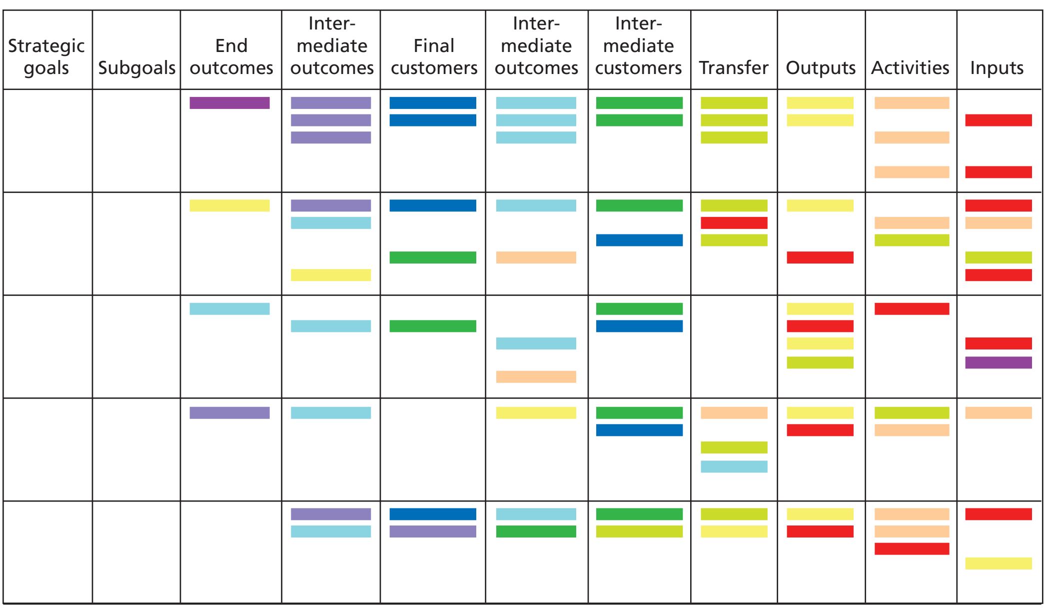
Library of Science) to identify hits from searches for NIOSH report titles; and identifying patented technologies related to the specific research program.

Analyzing Information in the Outcome Worksheet

In addition to identifying and structuring information, the format of the outcome worksheets enables quick review and analysis of a large amount of information. Specifically, we reviewed the outcome worksheets to determine whether (1) information was missing or inappropriately categorized and (2) information across the columns could be causally linked. Figure 4.2 provides a schematic of an initial draft of the outcome worksheet.

In Figure 4.2, some cells are completely empty, which is an indication that some information in the causal path is missing. However, the outcome worksheet does more than indicate that information is missing. It also identifies specifically which type of information is missing in the causal path. Is it the intermediate outcome from the final customer? If so, this can cue program managers about whom to contact in order to track down this information. Other cells contain a mix of different-colored bars, which indicates inappropriately categorized information. Similar to developing the logic models, determining the appropriate category for some information is not always

Figure 4.2
A Schematic of an Initial Draft of an Outcome Worksheet



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easy. For example, a presentation at a conference, should that be considered an output or a transfer activity? It depends, in part, on the audience and purpose of the presentation. Discerning incorrectly categorized information is easier to accomplish when the information is in the form of a worksheet on which the causal thread can be followed. Thus, a major advantage of the outcome worksheet is that it helped research programs address both the questions, “Do I have the right information?” and “Is the information in the right place?”

Displaying the linkages between information in the columns is one of the most important functions of the outcome worksheet. Figure 4.3 shows an early draft of an outcome worksheet that was prepared from the Hearing Loss Prevention program.

Note the causal linkages between the activity of “Construct a hearing-protector testing lab,” the output of “Testing laboratory for hearing protector,” and the transfer activity of “Access to laboratory,” which is highlighted in orange in Figure 4.3. Beyond this point, the link from this activity to the end outcome of decreased noise exposure to EPA workers is unclear. In cases like this, the program managers most likely conducted follow-up research to determine whether there was a connection to the end outcome. For example, the program manager may contact the intermediate customer—U.S. Army Aeromedical Research Laboratory—to determine whether it conducted any testing at the hearing-protector laboratory and, if so, what the results were and whether they led to specific outcomes. Generally, if the programs could gather data indicating a response from the customer,[1] the information was included as part of the outcome worksheet. If not, the information may have been removed from the outcome worksheet and included in a discussion of emerging research activities in the evidence package. Similarly, note the linkages in blue between the output of the EarTalk system and the intermediate outcome of the marketed EarTalk system. In this path, the research activities and resources that contributed to this outcome need to be established.

At the end of the analysis, our goal was to have outcome worksheets with information filled in each cell, properly aligned in the correct columns and clearly established causal links between the information in the columns. Figure 4.4 presents a schematic of what the final version of an outcome worksheet should look like.

[1] The Framework Document (National Academies, 2007) defines *outcomes* as the customer’s response to outputs.

Figure 4.3
Outcome Worksheet: Hearing Loss Prevention Program

Strategic goals	Subgoals	End outcomes	Intermediate outcomes	Final customers	Intermediate outcomes	Intermediate customers	Transfer	Outputs	Activities	Inputs
		Decreased noise exposure to EPA workers	Workers at EPA laboratories use hearing protectors that meet ANSI standards	Workers who use hearing protection		U.S. Army Aeromedical Research Laboratory; GC Gentech	Access to laboratory	Testing laboratory for hearing protector	Construct hearing-protector testing lab	EPA request
							Workshop	Hearing-protector testing and rating methodologies	Develop methodology for testing and rating hearing protector	
							Conferences	Hearing-protector selection protocol	Develop hearing-protector selection protocol	
					CavCom has marketed EarTalk system	CavCom	Licensing of EarTalk system	EarTalk system		
					ANSI revision based on PPT-developed testing protocol	Standards-setting bodies				

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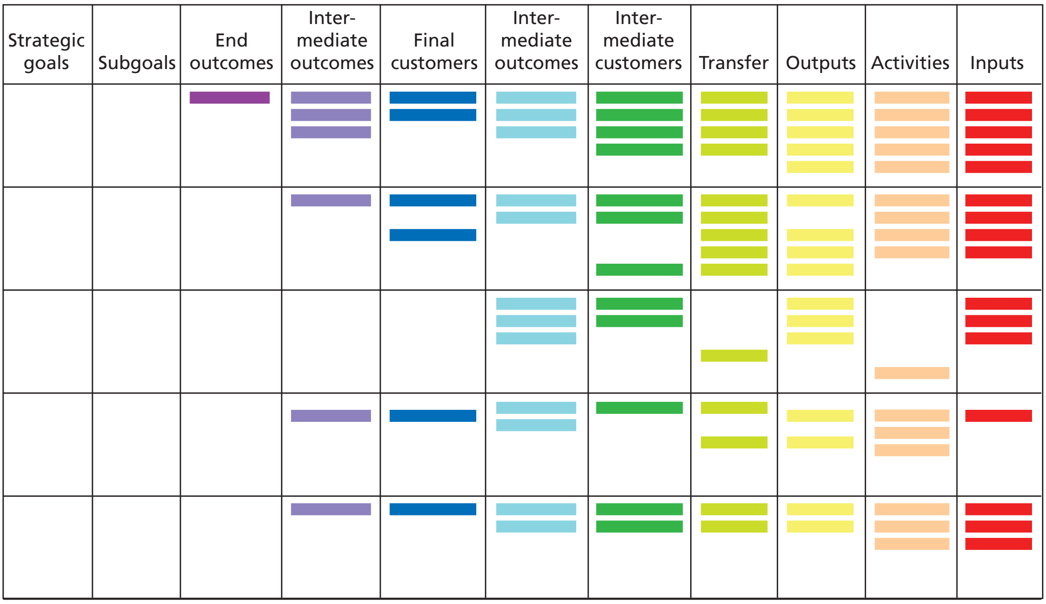
Figure 4.4
A Schematic of a Final Draft of an Outcome Worksheet



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Concluding Thoughts

Logic models and outcome worksheets were used as analytical tools in preparing for external review. Logic models promoted thinking through and describing impact pathways. Outcome worksheets helped trace specific instances of programs' contributions to outcomes. The next chapter focuses on the evidence package and the tool used to assist in communicating impact. There, the logic model and outcome worksheets played important roles. The logic model helped to determine the structure of the evidence package, and the outcome worksheets were used to create the key section of the evidence package: the outcome narrative. The next chapter covers the different elements and creation of the evidence package in detail.

CHAPTER FIVE

The Evidence Package

As the final part of our implementation phase, we helped the NIOSH programs develop a package of information to give to reviewers: the evidence package. Each evidence package included the data requested by the National Academies in the framework document as well as additional materials that the program deemed necessary to demonstrate impact. The outcome narrative is at the heart of the package. It provides a detailed account of how research inputs, activities, and outputs led to specific outcomes. In this chapter, we discuss the evidence package and present guidance for communicating the impacts of scientific research in the outcome narratives.

Communicating Impact

The central purpose of the evidence package is to communicate to reviewers that activities have contributed to societal outcomes. The reviewers were expected to use their expert judgment and knowledge of the field to evaluate the claims in the evidence package about the role of NIOSH programs in achieving intermediate outcomes (such as changes in workplace practices) or end outcomes (such as reductions in hazardous exposures). Thus, the information in the evidence package is designed to convey and support claims of impact. In this way, an evidence package differs from the drafting of the more-familiar research products, such as journal articles, research reports, or other products. In the following sections, we describe these differences.

Communicating to a Different Audience

Two key elements in communication are the audience and the communicator's purpose in communicating with that audience (Kinneavy, 1971). The starting point in creating the evidence package is thinking about the intended audience. In this case, the audience is the expert reviewers. Even though the reviewers may well be researchers themselves, they will be reading the evidence package from a different perspective—as evaluators. As members of a reading audience, researchers and evaluators are likely to differ in fundamental ways. To explore these differences and their implications, we developed a generic portrait of how researchers and evaluators are likely to differ as audiences (see Table 5.1).[1]

First, the level of knowledge about the subject at hand may differ significantly across these audiences. Researchers reading journal articles or reports in their own fields of research are likely to have substantial expertise in the field and to know just as much as the research author about the field itself. By contrast, evaluators' knowledge of the field may vary considerably. The evaluator could well be a researcher who understands a great deal about the field, but it is more likely that the evaluator is less knowledgeable about the research field per se; in fact, the evaluator may not be a researcher at all, but rather a policymaker, industry stakeholder, labor-union representative, or some other kind of stakeholder. These readers are less steeped in the research methods and discourse but likely to be highly knowledgeable about the real-world contexts in which the research is intended to make a difference.

Evaluators also use information differently. Researchers poring over journal articles or reports are typically trying to improve their understanding of the field, keep abreast of the latest findings, and understand methodological challenges involved in conducting studies. In contrast, evaluators read for a much narrower, more focused reason: to assess the validity of claims about the outcome of research, whether the

Table 5.1
A Tale of Two Audiences: Researchers and Evaluators

Characteristic	Researcher	Evaluator
Knowledge of subject	Usually vast	Variable, ranging from vast to sketchy
How they use information	To increase understanding	To make a judgment or decision
Attitude toward subject	Often desire to understand topic in detail	Want to know how information is relevant to them
Time constraints	Take maximum time possible to study topic	Want to digest information as quickly as possible
Focus	Validity of findings	Causal links: how studying the problem leads to societal improvement
Purpose of communicating to audience	Convey findings of research	Demonstrate impact of research
Nature of problem	Research	Societal
Desired result	Advance knowledge in research field	Inform judgment about research impact

[1] Much of the information in this table derives from conversations with communication analysts at RAND, whose distilled wisdom can be found in *Guidelines for Preparing Briefings* (1996).

claims made in the evidence package are valid and supported by the evidence presented, and, ultimately, the impact of the research.

These audiences also have different attitudes about the subject and a different time frame in which the information is used. Researchers possess an intrinsic interest in research methods and results and want to understand them in detail. They are likely to immerse themselves in presentations of findings. However, evaluators tend to approach information with a decisionmaking orientation. They have a judgment to make and approach the material with an eye on its relevance to the assessment. Evaluators want to absorb the information more quickly than they might if reading from a research orientation. They have been convened for a specific task and want to complete it as expeditiously as possible.

Along with these differences comes a difference in focus. Researchers reading a research publication, especially as peer reviewers, focus primarily on methodological validity and the soundness of the findings. Evaluators of evidence packages that focus on impact are focused on the causal links between the study of a particular problem and outcomes that represent societal improvement.

Communicating for a Different Purpose

It follows from these differences in audience orientation that the author of an evidence package has a more practical purpose in mind: informing the evaluators' decision about whether the package has made a convincing case for the impacts it has traced back to the research program under evaluation. Thus, evidence-package authors must answer the following questions for their audience:

- *So what?* How is this information going to help me assess impact?
- *Who cares?* Whom does this affect?
- *Who says?* What evidence do you have to substantiate your claim that links your research to outcomes?
- *And your point is?* What outcomes have you achieved?

Readers of evidence packages must come to a decision about whether the evidence presented support claims of impact. This decisionmaking orientation means that evaluators are looking for clear, concise, and accessible evidence packages that can be easily absorbed. Thus, simply collecting information (such as project descriptions) or outputs (such as journal articles) into an evidence package in the hopes that the "reader will make the necessary connections and do the hard work of tying the information together should be avoided" (Montgomery, 2003).

In the next section, we describe the guidance we shared with the NIOSH research programs for constructing the evidence package, leading to a more narrowly focused discussion of the key section, the outcome narrative.

The Structure of the Evidence Package

The evidence packages that the NIOSH research programs prepared followed a standard, uniform structure that mirrored the logic model.[2] As the conceptual blueprint for how the research program gets to outcomes, the logic model structure provided the basic organizational sequence of the evidence package, concluding with an account of outcomes and how the research contributed to them.

Most of the evidence packages consisted of the following sections: (1) introduction to NIOSH, (2) overview of the research program, (3) research program strategic goals and outcomes, and (4) vision for the future. The Respiratory Diseases Research Program (RDRP) described the outline of its evidence package in the following manner:

> The first two chapters of the evidence package provide introductions to NIOSH and RDRP. The next four chapters are disease-focused and address interstitial lung diseases, airways diseases, respiratory malignancies, and infectious diseases. An exposure-focused chapter addresses nanotechnology research. Finally, five activity-focused chapters address some of the more prominent institute activities needed to reduce work-related respiratory diseases. These activities include surveillance, [HETAB], emergency response and disaster preparedness, respirator policy, and sampling and analytical methods activities. A final chapter presents the RDRP vision for the future. (NIOSH undated[e])

The first section described NIOSH, including its organizational structure, mission, value, and strategic plans. It also included fiscal, staffing, and planning resources. The second section focused on the specific research program being reviewed—in this case, RDRP—and provided much of the information that the framework document outlined for describing inputs, activities, and outputs. This section discussed the production resources, such as personnel, funding, facilities, and equipment used by the research program. It also included planning resources, such as prior program evaluations of the research program, strategic-planning processes, and stakeholder input. The program's logic model was included in the second section along with a description of the types of activities, outputs, transfer, and customers of the program. The third, and usually the largest, section was the one on outcomes. In the case of RDRP, this section of the evidence package consisted of four chapters organized by disease focus. It featured the outcome narratives, which presented the evidence for impact and relevance by detailing how specific areas of research activities led to intermediate or end outcomes. The narrative section is the centerpiece of the evidence package. In effect, it provides the links across the components of the logic model. As such, it must do much of the package's heavy lifting: It must demonstrate the case for the research leading to

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2 Links to the NIOSH research program evidence packages can be found at NIOSH (2008c).

outcomes that will provide the evaluators with the evidence of impact they have been asked to judge.

Using Outcome Worksheets to Prepare Outcome Narratives

The outcome narrative consists of a standard template that includes the following five sections: Issue, Approach, Outputs and Transfer, Intermediate (and End) Outcomes, and What's Ahead. Each section includes a specific set of information. For example, the Issue section describes the major problem or considers what the research was trying to address, whereas Outputs and Transfer focuses specifically on the research products and how they are transferred to customers.

Figure 5.1 shows how the information from the outcome worksheet was used to create the outcome narrative.

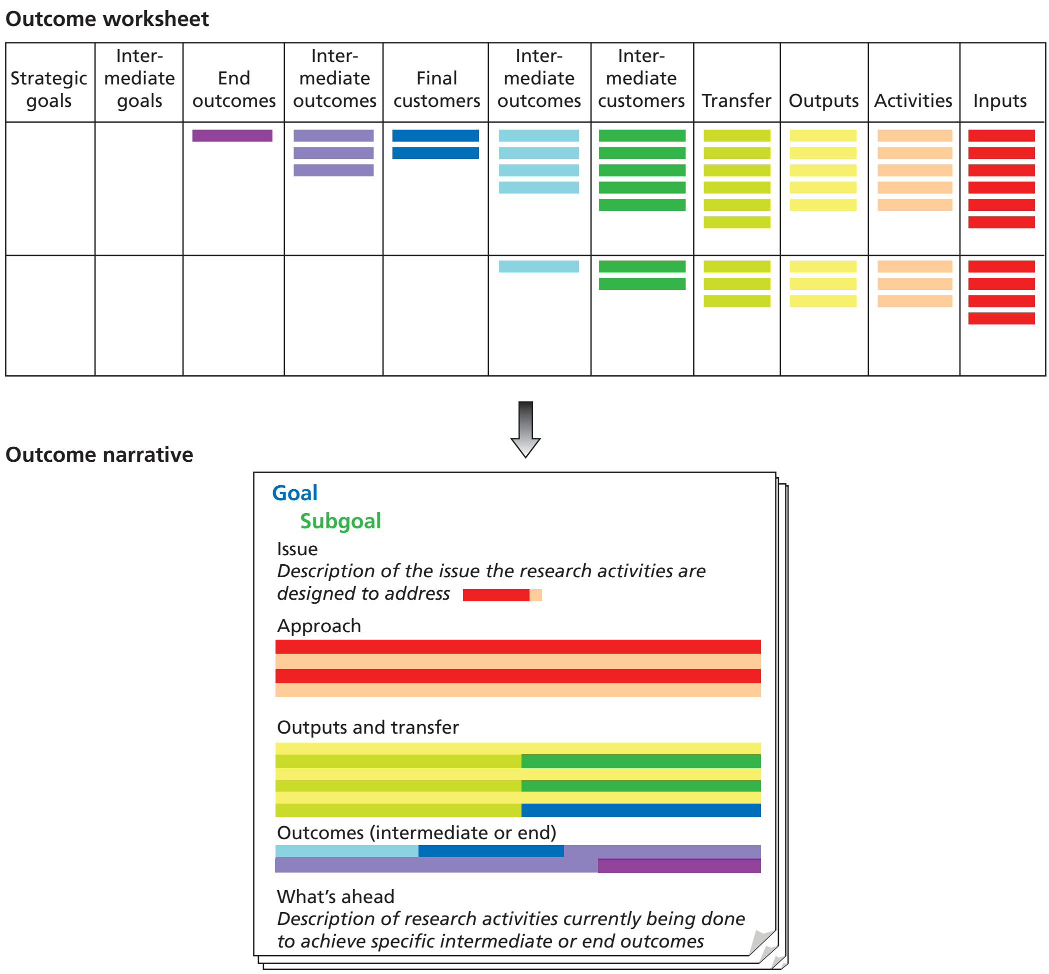
As described earlier, the colored bars indicate specific types of information that correlate with the logic model. Thus, the Issue section draws largely from the information on inputs, as they provide both the resources for conducting research activities and the guidance for determining which research activities to conduct. The Approach section describes the research activities that were conducted to address the issue. The Outputs and Transfer section includes four colors, corresponding to outputs, transfer, and intermediate and final customers. Each of these logic model elements are included in the Outputs and Transfer section, as it describes specific outputs, the transfer activities, and the customers who were the recipients of the transfer activities. Finally, the Intermediate (and End) Outcomes section describes the specific customers who received the outputs and the response to the outputs.

Writing the Outcome Narrative

The outcome worksheet provides a skeletal structure for the outcome narrative. Here, we fill in details about creating the sections of the narrative and provide some examples of effective narrative sections.

Issue: What is the major societal problem? The narrative should begin by clearly and concisely defining the issue and its significance, why it exists, and who is affected (Poling, undated). In the process of defining the issue, baseline data are helpful, as they help to define the scope of the problem. The focus should be on the issue area per se rather than the events that led to awareness of the issue. For example, in describing the problem of workplace hearing loss, it may be helpful but is not necessary to describe how understanding of the problem came to light or evolved; it is necessary only to describe the problem itself. It is also helpful to provide context that explains why this issue is important (such as the magnitude of the problem, e.g., the number of workers at risk and the severity of the risk) and to describe why the issue exists (for example, inadequate standards, lack of technology, tools, or materials to minimize risk, lack of

Figure 5.1
Translating the Outcome Worksheet to the Outcome Narrative



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knowledge, awareness or skills). A major challenge in this area is ensuring that the resolution of the issue is clearly linked to the program's end outcome. It is not sufficient to provide evidence that the problem has been reduced—there must also be a clear link between this outcome and the research program. Finally, it is important to describe the portion of the issue on which the program is focused and to describe how the program's work in this area will address the issue.

An excerpt from NIOSH's HHE evidence package provides an example of an effective issue statement:

> **Biological Hazards.** Until the early 1990s, thousands of American cities were allowed to dump their raw and treated domestic sewage directly into the nation's

> rivers, lakes, and bays. By 1992, EPA enacted regulations to stop this practice, and municipalities began separating the domestic sewage into liquid and solid streams. The treated solid component, referred to as biosolids, was approved for use as an agricultural soil amendment and crop fertilizer, and in reclamation of strip mines. Shortly after the EPA regulations were enacted, questions were raised about potential health risks to workers involved in land application of biosolids and to people living in surrounding communities. In 1994, the death of a child from staphylococcal septicemia one week after riding a three-wheeler over biosolids sparked concern in the local community, extensive media coverage, and attention by several employee groups, including the United Mine Workers.
>
> Based on data from 2002, an estimated 3.4 million dry tons of biosolids were used for agricultural purposes that year. Exposed occupational populations include wastewater treatment workers, haulers, applicators, and farmers. In 2004, the BLS estimated that there were 94,000 water and wastewater treatment plant and system operators in the U.S.
>
> In February 1998, the HHE Program received a request from the safety manager at the Butler County Department of Environmental Services in Ohio for assistance in evaluating workers' exposures during the processing and land application of biosolids. The HHE request stated that some long-term employees had reported headaches, stomach cramps, and diarrhea after working with the biosolids. The HHE Program also received two subsequent HHE requests in 1999 and 2002 to evaluate worker exposures during the handling of biosolids as part of mine reclamation activities and spreading of biosolids at the working face of a landfill. (NIOSH, undated[c])

This statement furnishes the important information concisely and clearly. The problem (exposure to hazardous biosolids in the workplace) is defined, and its significance is stated in terms of the estimated number of workers exposed.

Approach: What approach has been used to address this issue? This section describes the research strategies that have been used to address the issue. Ideally, it should move from general to specific. It should present the overall strategy before describing specific activities. The section should also explain how the methodology used by the program in question differs from others (such as partners or stakeholders) who may also work in this area. Use of the active voice in the approach section is important so that it is clear who did what. Although specificity in discussing approach and methodology is necessary, project descriptions and excessive research details should be avoided.

This section should not present merely the program's broad strategies or general action plan. The broad strategies may tackle only a subset of the motivating conditions and causes. The strategies really represent a cluster of specific activities, interventions, or services that the program will undertake to implement the overall strategies. These different strands need to be articulated clearly and separately. Again, we furnish an example from the HHE research program's evidence package:

> **Approach.** To determine the source of the illnesses, HHE investigators conducted monitoring to assess whether workers were exposed to aerosolized material from the waste stream or to the waste stream itself. The investigators examined whether the etiologic agent was suspended heavy metals, volatile organic compounds, or intestinal bacteria. To help understand the exposures and identify opportunities for prevention, the investigators interviewed affected employees to determine if work practices contributed to employee exposures.
>
> Over several months, three site visits were made to the Butler County landfill. HHE investigators observed work activities, interviewed five employees who worked directly with the land application process, and performed exposure monitoring. HHE investigators collected area and personal breathing zone air samples for culturable bacteria, endotoxin from Gram-negative bacteria, volatile organic compounds, and trace metals. Bulk samples of sewage sludge were also collected and analyzed to determine the extent of contamination with coliform bacteria.
>
> HHE investigators learned that the employees had each experienced at least one episode of gastrointestinal illness soon after working with the biosolids. Employees reported repeated intermittent episodes of gastrointestinal symptoms including diarrhea and abdominal cramping. The detection of enteric bacteria in the air and bulk samples collected during the evaluation indicated a potential for occupational exposure to disease-causing microorganisms. While the specific component(s) of the sewage sludge responsible for employees' symptoms were not determined, the nature and timing of the symptoms suggested occupational exposure by ingestion or inhalation of the sludge as a probable cause.
>
> In response to the two other requests, HHE investigators conducted field investigations at two facilities to evaluate worker exposures to culturable bacteria, endotoxin, and volatile organic compounds. The investigation involving strip mine reclamation activities at Power Operating, Inc. in Pennsylvania was completed following an initial site visit and medical interviews. Symptoms of nausea and upper respiratory irritation had been reported after a biosolids application. No additional biosolids applications occurred after the HHE request was received, precluding opportunities to conduct additional assessments. The HHE at the Outer Loop Landfill in Kentucky involved area and personal breathing zone monitoring for culturable bacteria and endotoxin during dumping and spreading of biosolids at the working face of the landfill. Environmental monitoring data showed exposure to culturable enteric organisms and endotoxin. (NIOSH, undated[c])

This discussion is notable for its skill in narrowing the issue down to a specific research topic—exposure to aerosolized waste material—a clear discussion of the activities involved in studying this topic, and the methodologies that guided these activities.

Outputs and Transfer: What were the major outputs from this research area? How and to whom were the products transferred? This section highlights the relevance of outputs and transfer activities. The discussion should be precise in describing outputs and provide sufficient context for understanding significance of outputs. It should avoid bulleted lists of outputs and transfers, moving detailed citation information to a supporting-evidence section. Where appropriate, the section should indicate customer demand for outputs and emphasize the proactive role of the research program in transferring program-generated information to intermediate and final customers. Both formal and informal venues for transferring information should be highlighted.

Again, the HHE example is useful:

> **Outputs and Transfer.** HHE investigators produced two numbered HHE reports [Burton and Trout, 1999; Delaney, 2003] and an HHE letter report. The reports included recommendations to improve personal hygiene, modify work practices, and use personal protective equipment to minimize exposure to biosolids, and enhance employee training regarding these issues. HHE investigators contributed to the development of a NIOSH guidance document on controlling potential occupational [hazards] related to exposure to Class B biosolids (defined as those that are treated but still contain detectible levels of pathogens) [NIOSH, 2000]. The document was revised in 2002, but the recommendations, many of which were derived from the initial HHE report, remained unchanged [NIOSH, 2002]. The original NIOSH document was republished in the Journal of Applied Occupational and Environmental Hygiene ["Workers Exposed to Class B Biosolids During and After Field Application," 2001].
>
> The principal HHE investigator was invited to make presentations at an EPA meeting, a meeting of the Kentucky-Tennessee Water Environment Association, and the American Industrial Hygiene Conference and Exposition. To ensure that worker safety and health issues were being adequately addressed, EPA also invited the principal HHE investigator to serve on the Pathogen Equivalency Committee, which reviews applications for new waste treatment processes.
>
> Amidst growing concern and allegations of potential health hazards from biosolids applications, and following a hearing by the U.S. House of Representatives Science Committee on municipal waste disposal, EPA requested that the National Research Council (NRC) of the National Academy of Sciences review the science and epidemiology surrounding biosolids. Because of the paucity of information on worker exposures to biosolids, the principal HHE investigator was invited to an NRC meeting to summarize results of the NIOSH HHEs. In 2002, the NRC published a report on [its] assessment, citing the NIOSH HHE in a chapter on the epidemiologic evidence of health effects associated with biosolids production and application [NRC, 2002]. (NIOSH, undated[c])

This discussion has a number of strengths: (1) It clearly enumerates the research outputs produced by HHE's activities; (2) it describes specific transfer activities undertaken to ensure that the research outputs found their way to users who needed the information (the EPA, the U.S. Congress, state-level organizations, and others) and (3) it indicates the pull aspect of the transfer activities and the demand on the part of the intermediate customer for information. It also provides context for the significance of these intermediate outcomes by highlighting the paucity of existing information on the subject, heightening the need for and interest in the program's outputs.

Intermediate (or End) Outcomes: What effect did the outputs have on the broader community? This section emphasizes the effect of program outputs. It establishes a causal thread by describing intermediate and final customers' responses to program outputs. The discussion plausibly links to some output. If there are multiple outcomes, the discussion should categorize the major areas of outcomes. Depending on the maturity of the research program, it may not have identifiable end outcomes. In these cases, it is appropriate to focus on the intermediate outcomes that have derived from the program activities. However, in cases in which intermediate outcomes appear to have led to end outcomes, including a section (such as Progress Toward End Outcomes) is important to emphasize the improved societal condition that can be linked to the research program.

The HHE example for this subsection is effective in linking the intermediate outcomes to the outputs while providing specific examples of customers and how they used the information (for example, to develop a new training program that incorporated hazard and hygiene recommendations):

> **Intermediate Outcomes.** The Ohio waste treatment facility used results from the HHE to develop a new training program for employees, incorporating the hazard and hygiene recommendations from the HHE report.
>
> Trade associations and other interested groups have disseminated information from these HHE reports to their members. Among the known organizations and media outlets that have disseminated this information are American City & County magazine; *Occupational Hazards* magazine; an occupational safety and health listserv hosted by Duke University; The Alliance For A Clean Environment, a non-profit environmental advocacy group; *AGnet*, a food safety network of the University of Guelph, Canada; and AgHealth News, a newsletter of the Agricultural Health and Safety Center of the University of California, Davis. (NIOSH, undated[c])

What's Ahead: What are some specific research activities currently under way or in planning to undertake in response to the problem? This is an optional section that showcases activities or outputs currently in progress or in the planning stages. It should include work that has not yet achieved intermediate-outcome status but with such status clearly on the horizon (three to five years out). The section should draw on the logic model blueprint to discuss how this work will lead to achievement of end outcomes. It should avoid a general or vague description of what is needed in the research field.

HHE research on chlorinated compounds included the following discussion in its What's Ahead section:

> The HHE Program is continuing to investigate respiratory symptoms, skin rash, and eye irritation among indoor water park employees at the Ohio facility, and is assisting the NIOSH Exposure Assessment [Coordinated] Emphasis Area in field testing modifications to the new air sampling method for chloramines. (NIOSH, undated[c])

As the example suggests, the discussion can be concise and straightforward. Even after the program achieved some important end outcomes, it continued to conduct work in this area to investigate ongoing problems and improve testing methods.

External factors: What are some actions or forces beyond the research institution's control that have important bearing on potential achievement of outcomes? In discussing the contribution of research to outcomes, it is important to identify external actions or forces, beyond the control of the research institution, that bear on the translation of outputs into outcomes. In NIOSH's case, industry, labor, regulators, or other entities may influence the ability of NIOSH outputs to enhance health and safety. This section may be a stand-alone one or be included with each section. The discussion should clearly articulate how the external factors have hindered or helped the achievement of outcomes (e.g., affected activities, production of outputs, or transfer). This discussion raises a potentially delicate issue: It should convey awareness of external factors without using them as an excuse or justification for not achieving goals or influencing outcomes. The section should ideally also include discussion of how the research program is responding or planning to respond to these external factors.

The HHE examples suggest how external factors played into the outcomes of its biohazard research and explains how, in this case, external factors added to public awareness of the problem, increasing interest in using research to inform a solution:

> **External Factors.** The extensive media coverage surrounding allegations of health problems and a death related to biosolids application served to focus attention on this as both an important occupational and public health issue. (NIOSH, undated[c])

CHAPTER SIX

Future Considerations for the Improvement and Application of Tools

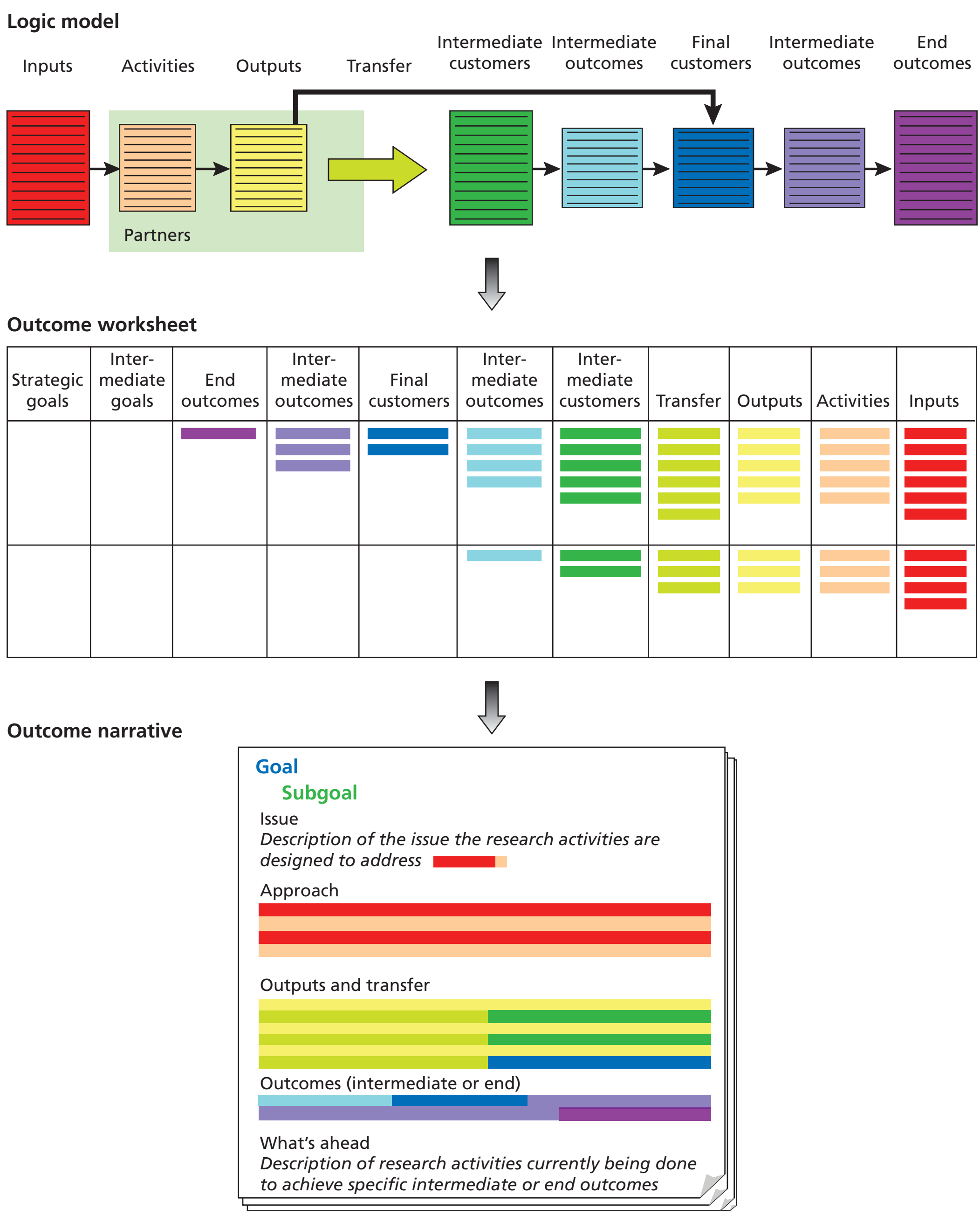
The tools discussed in this book are commonly used in evaluation research. The use of logic models to articulate program theory is fundamental to many types of evaluation. Outcome worksheets are similar to many structured frameworks that facilitate data organization for analytical purposes. Outcome narratives draw heavily on impact statements as a way to convey the societal benefits of research to a broad audience and on the case-study approach as a way to tell a program's research story. In this context, the utility of the tools discussed in this book lies in their collective use, which results in linking and aligning program theory to data collection and research communication. Figure 6.1 provides a schematic illustration of how these tools are linked.

As shown in Figure 6.1, the logic model served as the foundation for all the other tools. Methodologies for evaluating research impact require detailed models that articulate the program theory of how research activities contribute to outcomes. The logic model provided an overarching view of each of the research programs and served as the template for the outcome worksheets. The outcome worksheets were instrumental in identifying the specific data needed to show cases in which NIOSH research contributed to identifiable outcomes. The outcome narratives provided an organizational template that assisted programs in communicating their impact succinctly. Drawn from the outcome worksheets, the narratives presented the outcome evidence in a relatively accessible and concise format.

Limitations of the Tools

Despite their usefulness in preparing NIOSH programs for external review, these tools had limitations. Representing the role of external factors in the logic model pathways was one area of difficulty. External factors are included in the logic models as a line with arrows pointing upward beneath the logic model boxes. However, more attention could have been given to identifying some of the external factors and their influence in helping or hindering the achievement of outcomes. Better articulation in the logic models may have been helpful to display, where known, the relative magnitude of these factors. For example, in some NIOSH programs, the inability to control the

Figure 6.1
Linking Tools for Demonstrating and Communicating Impact



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budgetary allocation for research activities played a pivotal role in achieving outcomes. Not accounting for this in the logic model may have created a false sense of what the program could control.

External factors were not included in the outcome worksheet. We made initial attempts to add an "External Factors" cell within each of the columns to give programs an opportunity to describe how these factors affected each logic model element. For many research programs, the effect of an external factor was not limited solely to an input, activity, or output but had varying levels of influence throughout the path to outcomes. Articulating these diffuse effects in a spreadsheet format was not easy. External factors were discussed in the outcome narratives. However, given the importance of external factors in assessing a research program's contribution to outcomes, not integrating external factors into all three of the tools may have limited their applicability.

The format for the outcome worksheets also presented a number of challenges. The spreadsheet format, though helpful for organizing and aligning information in a single row or column, was not the best layout for displaying multiple rows and columns. This was particularly problematic when the programs tried to use the worksheets to review and summarize the outcomes associated with a particular strategic goal. Some of the programs found it difficult to work with the small cells of the spreadsheet. The cells were used to promote concise and succinct explanations; however, inserting text and adjusting for the small type was a hindrance in some cases.

In addition to the formatting issues, some of the programs found it difficult to trace backward from outcomes. In some cases, the degree of overlap among research activities made it difficult to distinguish the contribution of one set of activities from that of others. In other cases, programs had difficulty prioritizing the most-significant outcomes that emerged from their research activities within the designated time frame of review.

The outcome-narrative template was straightforward in its application. However, it was difficult to use for research programs that had not yet achieved outcomes. In some instances, we recommended using headings, such as "Progress Toward Outcomes" to describe outputs that had gotten as far as transfer but did not have identifiable customer use or application associated with them. The appropriate number of pages for the outcome narratives was also difficult to determine. On average, we advised five to seven pages, but many programs exceeded that limit, undermining the concision and succinctness objective we recommended for the programs.

Overall, none of the tools reflected the inherent complexities of research; in particular, they did not reflect the feedback loops that occur throughout the process. As discussed in Chapter Three, some simplification was necessary for communication purposes. However, it may have been useful to provide multiple logic models of the research program with varying levels of detail and allow the reviewers to choose the one most appropriate for their needs in assessing program impact.

Finally, many of the evidence packages themselves tended to be rather dense. The page count for the evidence package ranged from as high as 948 pages to as low as 99. Although some variation in the sizes of the evidence packages was expected, this extreme range may indicate that the standard format was not well-suited for all of the programs. Moreover, in most of the reviews, the ECs still requested additional information from the research programs. In some cases, the information requested was already included in their evidence packages but the organizational structure and the density of information in the packages made it difficult to access. Thus, providing better guideposts for finding information in the evidence package may have been helpful.

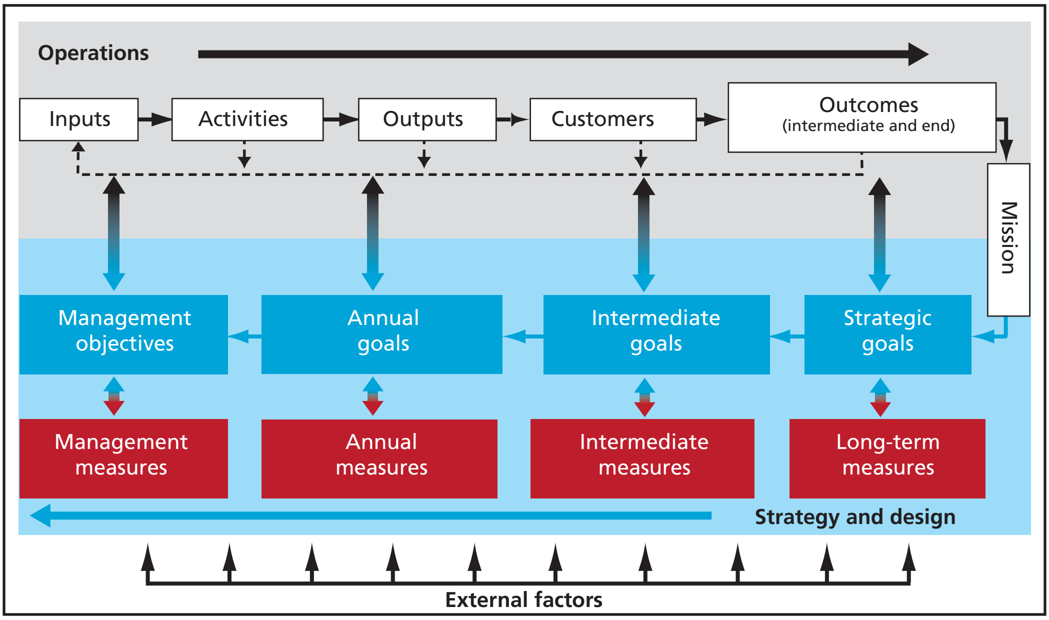
Other Uses for the Tools

In the United States and abroad, program-evaluation activities are becoming more integrated into overall systems of management oriented toward results (Cozzens, 2002). Thus, the tools described in this book have uses beyond supporting preparations for external review. For example, logic models can directly feed into project planning and outcome monitoring by program managers. Outcome monitoring can assist program managers in thinking through the data they will need to demonstrate the extent to which their program or even a specific body of research within the program is making a difference (Mayne, 1999). The logic model template shown in Figure 6.2 provides a structure for determining whether existing strategic, intermediate, and annual goals are aligned with program operations. These goals can drive the development of measures (shown in red in Figure 6.2) that can gauge the program's progress toward achieving outcomes.

In working with other agencies, we have used logic models for the development of a portfolio of measures that align with goals and derive from the logic model elements. Collectively, these measures provide a means of assessing (1) the use of resources to achieve management objectives, (2) the extent to which activities are implemented as expected, (3) the number and quality of products that are generated from research activities, (4) the number and quality of transfer activities to intermediate customers, and (5) the number and type of outcomes based on the customer response to the outputs.

In addition, measures derived from the logic model template can be combined with portfolio-management tools to enhance the benefits of outcome monitoring. *Portfolio management* refers to a class of methods used for balancing the potential value and risk of individual programs within a portfolio against an explicitly defined set of goals. There are several methods described in the literature for conducting portfolio management, including the balanced scorecard (Nair, 2004), applied information economics (Hubbard, 2007), IBM's Rational® method (Hanford, 2006), earned-value management (Fleming and Koppelman, 2005), and RAND's portfolio management

Figure 6.2
Logic Model Template as a Program Management Tool



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(PortMan) and assessment method (Silberglitt et al., 2004). Goals and measures developed from the logic model can be used for evaluating the current portfolio of R&D activities. Similarly, adjustments to the current R&D portfolio based on the results of portfolio management can be tracked and monitored using outcome analysis to assess the effect of these adjustments in specific societal outcomes. However, there may be a significant delay between when changes in a given portfolio are made and when changes in societal outcomes can be measured. One approach to improve the coupling between the two methods would be to use all relevant measures associated with the annual, intermediate, and strategic goals. Annual measures would provide information about impact of the most-recent changes to the portfolio on program outputs, while intermediate and strategic measures could be used to assess the impact of changes on previous portfolios. It would also be important that changes to the portfolio be executed incrementally in order to assess the actual impact on societal outcomes. Nonetheless, combining portfolio management with outcome analysis has the potential to provide a valuable capability to those seeking not only to achieve the highest potential near-term value for their current portfolio but also to ensure that they are achieving the maximum societal benefit.

The outcome worksheets are also important tools that could be used for outcome monitoring. The spreadsheet format enables research programs to look across the data in the table and identify which set of research activities have been linked to outcomes, assess the extent to which transfer activities have led to intended customer outcomes, and identify the range of intended and unintended outcomes from their outputs. Over time, these spreadsheets can become the foundation of a database that tracks uptake, adoption, and utility of research outputs by different customers. This could enable better strategic planning of transfer activities and working more effectively with partners at early project phases. As programs consider the causal linkages, they may realize that more data may need to be collected on factors that influence customer adoption of technologies rather than collecting data on outcome measures of customer adoption and use of certain technologies.

Evidence packages and outcome narratives are useful tools for communicating impact to audiences beyond just external reviewers. An effective outcome narrative can communicate to decisionmakers not only the impact of research programs but also their value to stakeholders, such as legislators, local officials, and the general public. These stakeholders prefer information that gets to the point quickly and clearly. The concise format and readable layout of the outcome narrative ensures that impacts can be accessed and appreciated by a broad community of stakeholders.

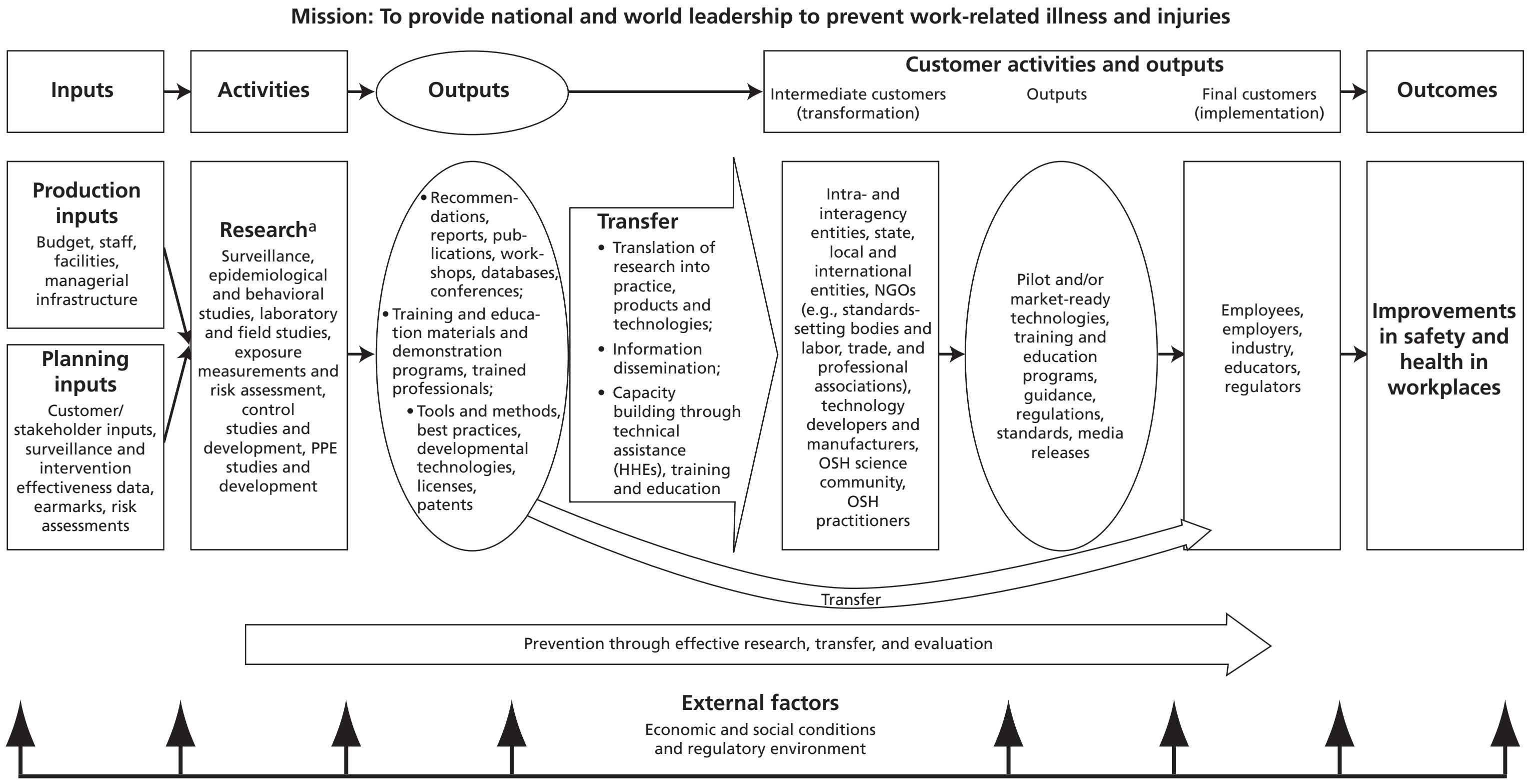
Clearly, more tools and methods are needed to map the causal connections between publicly funded research and its social benefits. However, putting the tools described here to rigorous use is an important step in determining whether federally funded research programs are achieving long-range societal goals.

APPENDIX

NIOSH Program Logic Model

This appendix presents the NIOSH program logic model.

Figure A.1
NIOSH Program Logic Model



SOURCE: National Academies (2007).

NOTE: ARC = agricultural research center. WHO = World Health Organization.

[a]Intramural and extramural, including domestic and international efforts, such as work conducted at ERCs, ARCs, and Global Network of the WHO Network of Collaborating Centres.

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