



NIOSH CONSTRUCTION  
PROGRAM REVIEW  
Expert Panel Review

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## External Review Panel Members for the NIOSH Construction Program Review

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## Executive Summary

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This NIOSH (National Institute for Occupational Safety and Health) Construction Program Review examines NIOSH's impact on U.S. occupational safety and health in the construction industry from 2007-2017. It is the latest in a series of NIOSH program reviews conducted by independent experts. The reviews provide expert feedback to NIOSH and the Construction Program regarding the relevance and impact, or potential for impact, of their work. This feedback is used to inform future Program decision-making, investments, and intellectual efforts to support NIOSH in its mission to reduce occupational illnesses, injuries, and hazards in the construction industry. The reviews are also conducted to meet the requirements of the Government Performance and Results Act (GPRA).

Using an evaluation method called "contribution analysis," designed to look at a program's "reasonable contribution" to end outcomes (reductions in fatalities, injuries, illnesses, and hazardous exposures), this Review focused on research and Research to Practice (r2p) efforts in five subject areas defined as high priority and with potential for impact within the NIOSH portfolio. These five areas are:

- Respirable crystalline silica (RCS) exposure in construction;
- Musculoskeletal disorders (MSDs) in construction;
- Noise and hearing loss;
- Highway work zones; and
- Preventing falls in construction.

NIOSH provided the Panel with a detailed evidence package describing activities, outputs, intermediate outcomes, and end outcomes for the five topics. After reviewing the document, NIOSH and CPWR (Center for Construction Research and Training) staff and researchers briefed Panel members at a face-to-face meeting, where they were provided with additional information and given an opportunity to ask questions and interact with researchers. The Panel then discussed their individual views and developed numeric scores for the NIOSH Construction Program.

Consistent with guidance from NIOSH, work on the five subject areas was not scored individually, but considered "as a whole" and given one score. The Review Panel gave the NIOSH Construction Program a total score of 9.5 out of 10. The relevance of the five subject areas was given a score of 5 out of 5, and their impact, or potential for impact, was given a score of 4.5 out of 5. For relevance, this means that the rationale for the activities completed by the Program is highly justified based on burden and need. For impact, the score is approximately midway between 1) major contribution and 2) some contribution and/or demonstrates great potential to contribute to end outcomes or well-accepted intermediate outcomes (see Appendix 2 for the scoring rubric). These scores reflect a very high level of performance within the Construction Program.

The Panel also identified specific issues that NIOSH should consider as it shapes the future of the Program. The following findings and recommendations are described in greater detail later in the report.

Consistent with its finding that the NIOSH Construction Program is highly relevant and impactful, the Panel recommends that NIOSH continue to conduct basic and applied research to improve construction worker health and safety. The effort should prioritize research in areas where improvement is needed most, as well as maintain a pipeline of research findings and developments for transfer and implementation.

The Panel believes that NIOSH r2p efforts have improved the use of its research and products in the construction community. The Panel also believes there is still significant work to be done in this area. The Panel recommends that NIOSH increase its marketing efforts to make construction employers, workers, and safety

professionals more aware of the products that could help them improve workplace safety. The Panel recommends additional research on effective methods to train and educate employers, as well as methods to encourage employers to develop and improve their safety and health programs. One strategy may be to emphasize the positive productivity and business effects employers often observe when they implement new or improved safety measures.

The Panel was impressed with NIOSH's development and increased use of computer, cell phone, tablet, and Internet-based technologies to accomplish r2p goals. These technologies create efficiencies and opportunities for large-scale impact that would not be possible without them. The Panel recommends that NIOSH produce and disseminate additional software and hardware products that help construction employers, workers, and safety professionals address construction hazards.

The Panel noted the challenge posed by smaller construction employers. Their employees are often at higher-than-average risk of injury and fatality because their employers often provide little or no protections. The Panel recommends additional research on methods to reach these employers, help them recognize their safety and health responsibilities, and motivate them to improve their safety practices.

The Panel found that many of the more significant intermediate outcomes included design or redesign of construction equipment. Safer construction equipment, when adopted by the industry, provides engineering controls that are more effective than other types of hazard controls. Other NIOSH research projects contributed to more effective personal protective equipment (PPE). The Panel recommends that NIOSH continue to prioritize research and r2p efforts that improve the safety features of PPE and construction equipment.

The Panel found that many of the significant intermediate outcomes involved changes to mandatory government standards, voluntary consensus standards, and other influential documents. The Panel recommends that NIOSH continue to prioritize research and r2p efforts that result in safer standards and other influential documents.

The Panel found that many of the significant intermediate outcomes were the results of partnerships with various organizations, including construction industry trade associations, professional associations, union organizations, consensus standards committees, and governmental bodies. The Panel recommends that NIOSH maintain their existing relationships and seek out stronger relationships with groups capable of helping them impact construction safety and health.

The Panel observed that the construction industry is changing rapidly as a result of advancements in artificial intelligence and robotics and a changing workforce. A critical activity to keep up with these developments and address new safety and health issues is horizon scanning and ongoing feedback from stakeholders. The Panel recommends more frequent reviews of projects within the Program, including ongoing informal feedback from stakeholders.

The remainder of this report covers background information, the review process, the Panel scores, more detailed findings and observations, and a fuller discussion of the Panel's findings.

## Background of the Review Process

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This section describes previous reviews of the NIOSH Construction Program, the contribution analysis evaluation theory used in this Review, the charge to the Panel, the Panel's review process, and the scoring method used.

Unless otherwise specified, all references to the NIOSH Construction Program include the National Construction Center (NCC). NIOSH created the NCC to focus safety and health research on the construction industry and address an important construction safety research gap. The duties of the NCC are:

- To directly link to the construction community. Through partnerships with industry stakeholders, the NCC bridges the gap between research and what happens on construction sites;
- To serve as a leader in applied construction research. The NCC identifies causes of safety and health risks, develops practical solutions to reduce those risks, and explores emerging hazards construction workers face on the job; and
- To communicate effective interventions to the construction industry. The NCC publicizes the results of research findings to make them available to anyone with an interest in construction industry safety and health. The NCC also provides training resources and technical services to apply research findings at the work site. Findings are presented at conferences, stakeholder meetings, in publications, and on the Internet.

[CPWR](#) is the current NCC.

### National Academies Review

From mid-2005 until the end of 2008, the National Academies conducted separate evaluation studies of eight NIOSH programs, including the Construction Program. The purpose of the reviews was to assess the impact and relevance of each program and to identify emerging issues. As "Science Advisors to the Nation," the National Academies and their component organizations, the National Research Council and the Institute of Medicine, provided rigorous, independent expert reviews.

In order to conduct these reviews in an orderly and consistent way, NIOSH charged the National Academies with assembling a study panel to develop a framework for the program evaluations. The framework established the standards and methods used in all eight reviews.<sup>1</sup> The basic definitions of key terms in the framework document (listed below) are still used today; the Panel has added examples to supplement some definitions and reflect additional outputs:

*Activities:* Efforts and work of the Program staff, grantees, and contractors (e.g., surveillance, health effects research, intervention research, health services research, information dissemination, training, technical assistance).

*Outputs:* Direct products of NIOSH programs that are logically related to the achievement of desirable and intended outcomes (e.g., publication in peer-reviewed journals, other publications, articles, recommendations, reports, website content, workshops and presentations, databases,

educational materials, new technologies, patents, computer software and applications, technical assistance).

*Intermediate outcomes:* Actions taken by stakeholders in response to NIOSH products or efforts (e.g., policy changes; production of standards or regulations; adoption of NIOSH-developed technologies; use of publications, technologies, methods, or recommendations by workers, industry, and occupational safety and health professionals in the field; use of NIOSH research in subsequent research by industry, government, and academic scientists).

*End outcomes:* Improvements in safety or health in the workplace – specifically, reductions in work-related injuries, illnesses, or deaths, or reductions in hazardous exposures in the workplace, that can be attributed to NIOSH efforts.

Since the NIOSH logic model was developed, the term “impact” has gained greater use as an umbrella term. As such, NIOSH has established the following definition of impact:

*Impact:* A collective term used to refer to both intermediate and end outcomes. Impacts can be qualitative (a success story) or quantitative (an increase or decrease in a numerical indicator). They can occur at any scale, ranging from a single workplace to the local, state, or national level.

The National Academies recruited a panel of experts for each NIOSH program review. Expertise included the content area experts, knowledge diffusion specialists, and program evaluation experts. Each panel received an evidence package of written materials from the managers of the NIOSH program under study. Program managers also presented oral evidence in face-to-face meetings with their panel. Once the Panel's report was drafted, it was reviewed by a second, independent panel of experts.

The National Academies’ review resulted in six formal recommendations to improve the NIOSH Construction Program:

- Research-to-Practice (r2p) efforts should involve individuals with training or with the experience and skills to create strategic diffusion and social marketing plans for National Institute for Occupational Safety and Health research and to evaluate such plans’ effectiveness.
- Consideration should be given to having the majority of r2p efforts of the Construction Program conducted through the National Construction Center.
- High-level attention should be given to determine how to provide program resources that are commensurate with a more robust pursuit of the Construction Program’s goals.
- The Construction Program coordinator and the Construction Program manager should both be devoted full-time to the Construction Program.
- The National Construction Center should continue to be used as an important component in the Construction Program.
- The program should establish a closer connection with the Occupational Safety and Health Administration (OSHA) and other regulatory standards organizations to help ensure that the program’s research is applied effectively in rule-making efforts.<sup>2</sup>

In August 2009, in response to the National Academies' recommendations, the Construction Program presented an initial implementation plan to the NIOSH Board of Scientific Counselors (BSC). The BSC commented on the plan and provided an additional recommendation:

- An increased focus on developing a specific r2p plan for construction in conjunction with the National Construction Center, the National Occupational Research Agenda (NORA) Construction Sector Council, and OSHA. The plan should focus on those areas where causes of injuries, illnesses, and fatalities are known and solutions have been identified and are readily available. Dramatic impacts could be achieved in a relatively short time period.<sup>3</sup>

In its August 2012 *Report to the NIOSH Board of Scientific Counselors*, the NIOSH Construction Program summarized its progress and impact in implementing BSC and National Academies recommendations. In July 2014, an update to the 2012 report informed the BSC on the Construction Program's progress toward the same recommendations.<sup>4</sup>

NIOSH has used the National Academies and BSC recommendations to guide its construction safety and health research and r2p program since 2009. The NIOSH Construction Program also uses recommendations from the NORA Construction Sector Council to guide its research efforts. The NORA Construction Sector Council established 15 research and r2p goals in 2008;<sup>5</sup> progress on meeting those goals was reviewed in 2013.<sup>6</sup> The NIOSH Office of Extramural Programs conducted a recent analysis of the NIOSH Construction Program, addressing all 15 NORA strategic goals by extramural and intramural researchers.<sup>7,8</sup> The NORA Construction Sector Council revised the Occupational Research Agenda for Construction in 2018.<sup>9</sup> The overall result is that NIOSH uses a combination of BSC recommendations, Program Review recommendations, NORA goals, and other inputs (e.g., budget, policy, and personnel considerations) to administer the Construction Program.

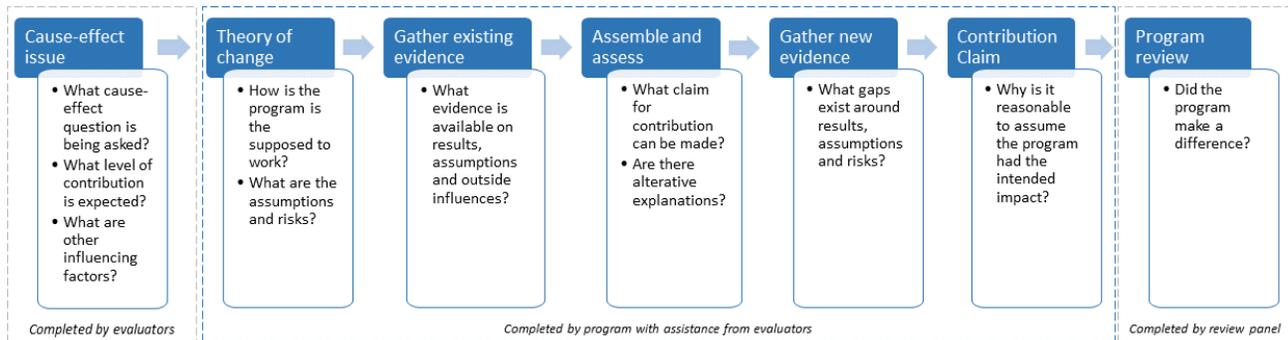
## The NIOSH Logic Model and Contribution Analysis Evaluation Method

Evaluation of research programs, including those at NIOSH, is a difficult exercise. NIOSH works within a complex environment with many influencing factors, most beyond its direct control. The effects of research on end outcomes, particularly health-related research, can take many years to occur; oftentimes, health outcomes are not accurately recognized and diagnosed as resulting from occupational exposure. At the beginning of any given research project, it is difficult to predict the impact the research may eventually have on occupational safety and health. The end outcomes influenced by these activities and outputs are affected by many factors, including economic changes and employment shifts. Economic influences may be even more important in the construction industry, where changes in the economy are often felt more strongly than other industrial sectors. Given these measurement difficulties, NIOSH evaluates its programs using contribution analysis concepts first introduced by John Mayne in 2001, and refined in 2011.<sup>10, 11</sup>

Contribution analysis aims to demonstrate that a program is an important influencing factor in observed outcomes and that it made an important difference. This is accomplished by assembling enough evidence to reach a "plausible association" between the work of the program and the observed outcomes. In other words, "A reasonable person would agree from the evidence and argument that a program has made an important contribution to the observed result."<sup>11</sup> Not only does this approach answer the question of whether the program made a difference, but it also helps programs understand how and why those impacts occurred through the explanation of a theory of change.

NIOSH has modified Mayne's contribution analysis framework (Figure 1) because it was originally developed to evaluate social programs, rather than research programs. The modified version places less emphasis on assumptions and risks and adds expert panel peer review as an additional step at the end.

Figure 1. Contribution Analysis Steps



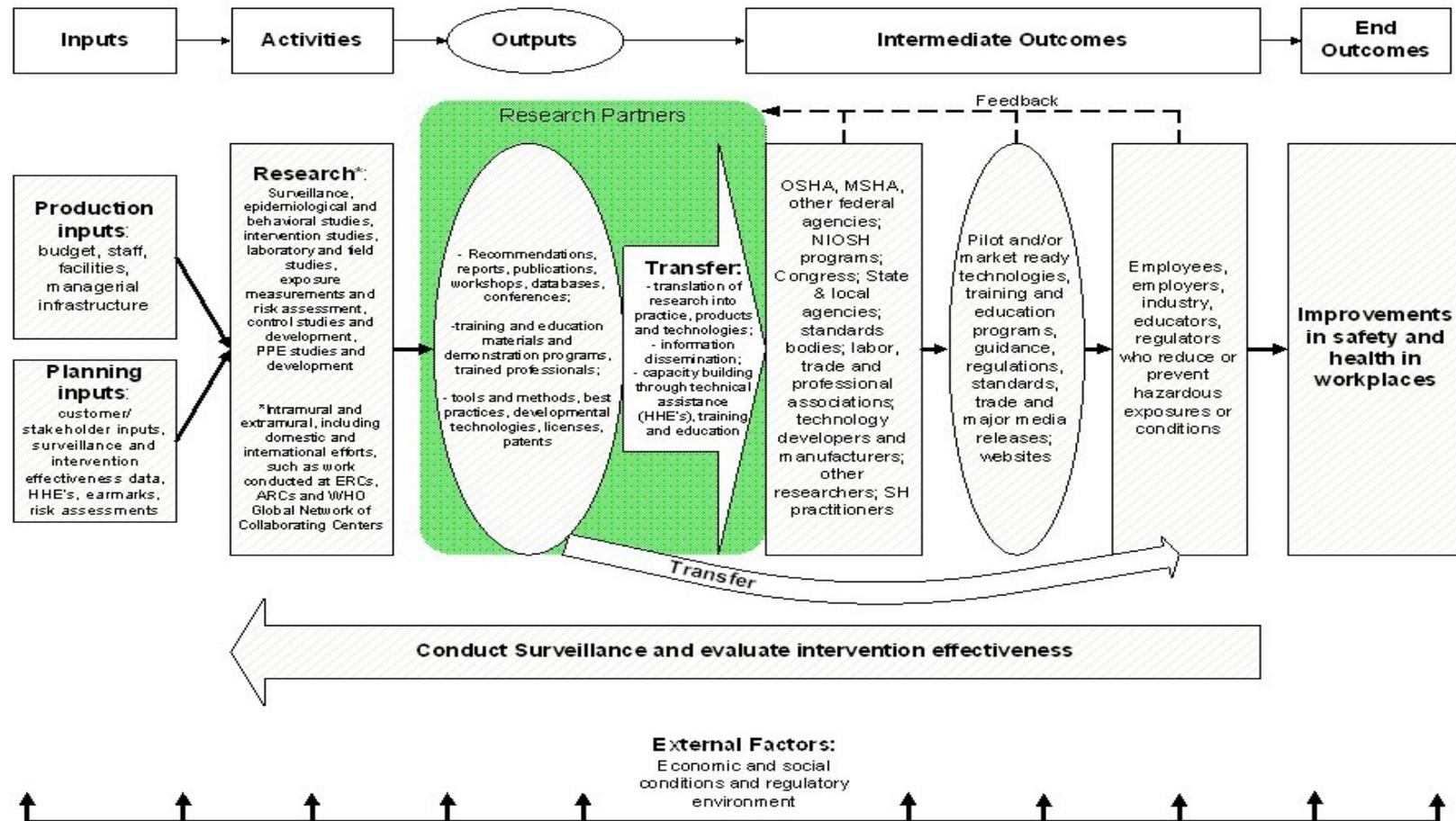
The theory of change provides an explanation of how the program is supposed to contribute to a given end outcome. NIOSH programs have outlined their specific theories of change using logic models. The NIOSH logic model is shown in Figure 2. Each arrow in the model signifies an underlying assumption or risk. In other words, the arrows represent conditions or events that need to occur for the contribution links to plausibly work. This is consistent with the NIOSH definition of Research to Practice:

Research to Practice (r2p) is an approach to collaborations with partners and stakeholders on the use, adoption, and adaptation of NIOSH knowledge, interventions, and technologies. We need to move research into practice in order to reduce and eliminate injuries, illness, and fatalities. At NIOSH, we feel it is important to work with our partners to develop effective products, translate research findings into practice, target dissemination efforts, and evaluate and demonstrate the effectiveness of these efforts in improving worker health and safety.

NIOSH chose to put less emphasis on detailed assumptions and risks because they are fairly standard across its programs. Outputs and activities are under the direct control of NIOSH; however, NIOSH can only influence future outcomes, as they rely on the actions of other parties. As the process progresses from activities and outputs, transfer and translation, intermediate outcomes, and ultimately end outcomes, NIOSH influence diminishes while the influence of other parties increases. Drawing from Morton,<sup>12</sup> the typical assumption of outputs is that they reach the right audience and that the information is timely, pertinent, and credible. The risk is that the information does not reach the right people or does not meet their needs. For intermediate outcomes, the assumption is that partners are willing and able to take action, while the risk is that partners do not take action due to factors such as financial constraints, competing priorities, and priority shifts. The assumption underlying the occurrence of end outcomes is that enough partners take action to reach a critical mass and effect change, while the risk is that not enough partners take action or that external forces counteract partner actions.

Once the theory of change is established, the next step is to gather readily available evidence and assess the strengths and weaknesses of the theory. Mayne<sup>11</sup> suggests gathering evidence through observation, conversations with stakeholders, searching the literature, and critical thought and discussion. Once the evidence is compiled, the next step is to assemble it and assess the strengths and weaknesses of the change theory. Alternative explanations are also examined to recognize plausible rival explanations that may also fully or partially affect end outcomes.

Figure 2. NIOSH Logic Model



NIOSH programs are continuously assembling evidence to see how their contributions have resulted in impacts. These efforts focus on shorter-term outcomes, the appropriate level of contribution analysis for research programs, as opposed to long-term outcomes that cannot be expected to occur for years.<sup>10</sup> In the NIOSH program evaluations, alternative explanations acknowledge the work of other individuals and organizations toward the same occupational safety and health issues during a similar time frame. Consistent with contribution analysis, NIOSH acknowledges that many organizations and groups are actively contributing in the effort to reduce workplace injuries and illnesses, and that NIOSH is but one contributor. Some of these contributors are:

- Federal OSHA and the 28 OSHA-approved State OSHA Plans;
- Workers' compensation providers, including state workers' compensation agencies and private sector insurance companies;
- Trade associations;
- Labor unions;
- Construction employers;
- Construction project owners;
- Safety professionals;
- Professional associations;
- The OSHA-funded State Consultation programs;
- The OSHA Training Institute Education Centers;
- Safety advocates;
- Safety researchers funded by NIOSH and other sources;
- Federal and State Departments of Transportation; and
- Equipment and technology manufacturers and providers.

## Performance Reporting

Under the GPRA Modernization Act of 2010, federal programs are required to have performance measures that meet minimum standards. Programs must describe trends in the results, and if applicable, explain why targets were not met in an accompanying narrative. These measures are reported annually as part of the Centers for Disease Control and Prevention's (CDC's) budget justification. NIOSH has a GPRA performance measure that relies on the results of program reviews, and has committed to doing one or two reviews per year for five years (fiscal years 2017-2021).

Acceptable performance under the GPRA measure is defined as a score of 7 out of 10 or greater in external program review. The overall 10-point maximum score results from combined individual scores on relevance (1-5) and impact (1-5) using the scoring method found in the Appendix 2 Summary Panel Scoresheet.

## The Charge to the Panel

NIOSH gave the Panel a broad charge to conduct their Review. The Panel was asked to review Construction Program information provided by NIOSH, develop individual scores for relevance and impact to calculate a group average, and to provide their rationale for the scores. The Panel was also asked to provide findings and suggestions for improving the Construction program. The group was not asked to develop consensus opinions, but rather, to provide individual views, which are synthesized in this report. When the individual views were unanimous, the observation is attributed to the “Panel.”

The Review is intended to provide expert feedback to the NIOSH Construction program regarding the relevance and impact, or potential impact, of their work. This feedback will be used by NIOSH to inform future program decision-making, investments, and intellectual efforts to support NIOSH in its mission to reduce occupational illnesses, injuries, and hazards in the construction industry.

The Review covered five specific subject areas (listed below) within the NIOSH portfolio, representing approximately half of the NIOSH Construction Program. The Program is working on many other construction safety, health, and r2p issues not included in this Review. The five subject areas were chosen because 1) they have numerous intermediate outcomes and are ripe (mature enough) for evaluation; 2) they represent areas with significant exposure to hazards resulting in numerous injuries, illnesses, and fatalities (burden); and 3) NIOSH has invested many resources (funds, personnel, and intellectual effort) to deal with each issue, covering a period of many years.

The five subject areas were:

- Respirable crystalline silica (RCS or silica) research in construction;
- Musculoskeletal disorders (MSDs) in construction;
- Noise and hearing loss in construction;
- Highway work zones; and
- Preventing falls in construction.

## The Review Process and Scoring Method

The review process started with a presentation by NIOSH evaluation staff to educate the Panel about the process and evaluation theory to be used. NIOSH then provided Panel members with the 326-page evidence package, and each Panel member reviewed and studied the descriptions of the five subject areas.<sup>13</sup>

Included for each subject area was:

- An introduction/background section;
- A description of the evaluation logic model, inputs, stakeholders, and contributing staff;
- A discussion of the activities, outputs, transfers, translations, and intermediate outcomes;
- End outcomes;
- Alternative explanations; and
- References.

Of particular value to the Panel were the descriptions of hundreds of activities and outputs, including 157 intermediate outcomes and available evidence of end outcomes. The activities, outputs, and intermediate outcomes are the evidence Panel members used to develop their relevance and impact scores. The intermediate outcomes were the primary source of information for the Panel, and vary widely. Some examples are:

- NIOSH articles cited in other journal articles;
- Participation in awareness campaigns;
- Distribution and use of guidance products, publications, applications, and software products;
- Development or support of equipment designs that eliminate or reduce hazards;
- New or revised voluntary consensus standards and other influential documents; and
- New or revised state, federal, or international safety and health standards.

Intermediate outcomes were included if they were the result of research activities completed by the NIOSH Construction Program (both intramural and extramural) or the NCC. Intermediate outcomes from NIOSH non-construction programs were also included if they had impacts in the construction industry. Some intermediate outcomes are the result of research conducted before 2007–2017, and are included if one or more intermediate outcomes occurred within the 2007-2017 time frame. Intermediate outcomes also include impacts on non-construction occupational populations if the Construction Program contributed to those impacts. Intermediate outcomes also include impacts observed outside the United States when the NIOSH research affected worker safety, influenced international safety research, or helped shape international consensus standards. There were 157 intermediate outcomes were identified by NIOSH, NCC, and extramural research staff; it is possible, perhaps even likely, that there are additional impacts that have not been documented because staff are unaware of them.

After reviewing the evidence package, the Panel held a conference call with NIOSH evaluation staff to ensure they understood the information and its context, to clarify issues, and to ask questions. The Panel then attended a meeting in Atlanta to advance their knowledge of the Construction Review Program. On the first day, NIOSH, CPWR, and extramural researchers briefed the Panel on activities and outcomes described in the evidence package and answered Panel questions. On the second day, the Panel met privately to discuss the scores, the rationale for the scores, findings, and observations, and potential recommendations. Following the meeting, individual Panel members sent the Panel chair their scores and suggestions for the Report.

The Panel chair then prepared a first draft of the Report and sent it to the Panel members for their review and input. Their feedback was incorporated, the Report was reviewed and refined by a technical editor, and then forwarded to NIOSH staff. NIOSH will prepare a response to this Panel Report, which will be posted as a separate document.

The scoring method was straightforward: each Panel member developed their numeric scores for relevance and impact and rated them on a 1-5 scale. Panel members used the NIOSH Construction Program Panel Scoresheet and rubric found in Appendix 2 to provide more consistent scoring criteria. The Panel relevance and impact scores are the mean of these individual scores. When the two scores are added together, the total evaluation score has a maximum value of 10.

## Acknowledgements

The Panel would like to thank the many people that provided information and helped guide the Construction Program Review. Thanks to Dr. Amia Downes and Karen Busch of NIOSH's Office of the Director for their guidance on evaluation processes and methods. Thanks to Dr. Christine Branche, Dr. Scott Earnest, and CDR Elizabeth Garza of the NIOSH Construction Program for providing information and briefing the Panel. Thanks to the presenters at the evaluation meeting who briefed the Panel on their research efforts and answered the Panel's many questions. These included Chris Trahan Cain, Eileen Betit, CAPT Chuck Kardous, Dr. David Rempel, Dr. Alan Echt, and Dr. Thomas McDowell. Thanks also to the many people who contributed to the evidence package. The Panel also thanks David Frye, Mary Dawson, and Leslie Hamlin for providing the Panel with expert support and guidance.

The Panel extends a special thanks to Dr. John Mroszczyk, who recruited the Panel members and was scheduled to serve as the Panel Chair. Due to unforeseen circumstances, John was unable to continue with the Panel's work. We all wish him well.

## Panel Findings

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The Review Panel gave the combined NIOSH construction subject areas a total score of 9.5 on a 1-10 scale. The relevance of the five subject areas was given a score of 5, and their impact, or potential for impact, was given a score of 4.5. For relevance, this means that the rationale for the activities completed by the Program is highly justified based on burden and need. For impact, the score is approximately midway between 1) major contribution and 2) some contribution and/or demonstrates great potential to contribute to end outcomes or well-accepted intermediate outcomes (see Appendix 2 for the scoring rubric).

### Relevance

All five members of the Panel gave the Construction Program a relevance rating of 5.0, a rating they felt the Program easily merited; one Panel member felt the Program deserved a score of “5+.” Several Panelists felt the topics represented the day-to-day safety challenges often found on construction sites, noting the hazardous nature of construction work in general, stating that construction jobs are some of the most dangerous in the country, with the highest fatality rate of all industry sectors. The Panelists found the relevance of the five subject areas to be very high and among the most significant risks leading to construction worker injury, illness, and death. One Panelist noted that the falls and struck-by and caught-in-between hazards addressed by the research account for three of OSHA’s Focus Four hazards, which are the leading causes of fatalities in construction year-after-year. Another Panelist observed that the Program’s efforts addressed a balance of immediate safety concerns, as well as long-term health concerns.

One Panelist felt that NIOSH research activities demonstrated a focus on the high priority areas of need for improving construction worker health and safety. The research priorities were identified through a combination of accumulated construction worker injury and health data and input from employer and worker organizations. This Panelist observed that the receptiveness of industry and labor in many of these efforts is also a strong indicator of relevance.

The large number of exposures, injuries, illnesses, and fatalities occurring in the five subject areas supports this rating. OSHA estimates 850,000 workers face hazardous exposures to silica each year, with hundreds of workers dying each year from silicosis and other diseases caused by hazardous exposure to RCS.<sup>14</sup>

MSDs harm and disable thousands of workers. Private sector employers reported 285,950 MSDs resulting in days away from work (DAFW) in 2016, accounting for 32% of the 892,270 total private sector DAFW occupational injuries and illnesses.<sup>15,16</sup>

Approximately 44% of construction workers report exposure to hazardous noise.<sup>17</sup> Recent studies found that 25% of construction workers have a hearing impairment in at least one ear,<sup>18</sup> 16% have hearing impairment in both ears, and 7% have tinnitus (hearing ringing, roaring, or buzzing sounds).<sup>19</sup> From 1982-2014, approximately 750 individuals (workers and non-workers) died in work zone crashes.<sup>20</sup> From 2013-2015, 1,571 workers died at road construction sites (averaging more than 100 per year).<sup>21</sup> During this same time frame, more than 40,300 workers sustained DAFW injuries due to falls, with between 267 to 448 workers per year dying from falls.<sup>22</sup>

Clearly, all five subject areas are highly relevant to construction safety and health and consistent with the NORA goals to conduct applied research, r2p research, and emerging issues research. The NIOSH Construction Program prioritized and focused on the NORA construction goals that had the highest injury and debilitating occupational health hazards.

One Panel member observed that NIOSH construction researchers worked with partners in industry, labor, trade associations, professional organizations, and academia to conduct research and translate it to the construction industry, while another observed that the research studies involved a tremendous amount of effort on the part of NIOSH and extramural researchers. This Panelist found the results to be highly relevant to the needs of the construction industry.

## Impact

The five members of the Panel gave the Construction Program impact ratings ranging from 4.0 to 5.0, with an average score of 4.5. The high impact scores reflect Panelists' views that the Construction Program has made substantial progress in encouraging stakeholder use of safety and health research, equipment designs, and r2p products, which creates impact when used by those in the construction industry and the safety and health professions. Several Panel members noted that the Program provided valid research to support safety practices, useful tools for the construction industry, and effective training materials for the workforce.

All Panelists observed that NIOSH research support of the OSHA silica standard, and its implementation, will have significant health impacts in future years by reducing RCS illnesses and fatalities. Work on MSD prevention, including drilling equipment design and hand-arm vibration research, have significant potential to further reduce work-related exposures to hazardous levels of force, vibration, repetitive motion, and awkward posture. Similarly, work on noise control and hearing loss prevention have potential impacts on this common, life-altering construction health problem. Highway work zone research has resulted in numerous products to protect workers in this hazardous environment. Several Panelists pointed out the success of the National Campaign to Prevent Falls in Construction hazard awareness program and the National Safety Stand-Down to Prevent Falls in Construction. Through these campaigns, NIOSH, CPWR, and OSHA pulled together more than 100 partners, achieving participation from thousands of employers and millions of workers.

While the Panel was charged with evaluating the impact of the five subject areas as a whole, we include several impact observations of the individual safety topics in the next section.

## Observations and Findings

### General Findings

The Panel believes that the Construction Program has improved the recognition and use of its products by various stakeholders through its r2p processes, publications, and web pages. The Panel also believes that there is still much work to be done in this area. There is an ongoing need for dissemination of new research, as well as to encourage the use of existing research and products. The Panel found that NIOSH research and r2p efforts are often unknown in the construction industry and the safety and health community, and this limits the ability of r2p efforts to affect safety and health changes in the construction industry (See recommendations 2, 4, 5, 8, 9, 10, and 11).

The Panelists pointed out the impact related to an increased use of computer, cell phone, tablet, and Internet-based technologies to accomplish NIOSH's r2p goals. Because of ongoing advances in technology hardware and software, many of these tools were impossible, impractical, or infeasible during previous evaluation periods. One Panel member observed that, "The sound level meter app, ladder app, and the [silica-safe website](#) are streamlining safety information and education into quick reference guides for a fast-paced industry, reaching across generations to communicate hazards and protective measures. The foresight of NIOSH to leap into application tools enables construction personnel to use technology to recognize hazards and plan protective

measures.” Several Panel members pointed out the impact and efficiencies of using these technologies for outreach efforts. Focusing on the [silica-safe website’s Create-A-Plan to Control the Dust](#) pre-job planning software tool, they noted that this interactive site has allowed NIOSH to provide easy, inexpensive, customized action plans to large numbers of employers with a reasonable amount of staff and other resources. Given budget constraints and practical considerations, this level of public service would be impossible without the use of information technology products (See recommendation 3).

The Panel observed that 90% of construction establishments employ fewer than 20 employees, accounting for more than one-third of construction workers in the United States. Many of these firms have been in existence for only one or two years.<sup>23</sup> The owners and supervisors are often not trained or educated about safety measures, and may not understand their responsibility to protect workers. They are often burdened by task overload as they try to meet multiple business goals for production, schedule, quality, safety, and other issues. OSHA violation data indicate that large numbers of small construction firms do not provide their workers with basic workplace protections. Young Hispanic workers employed by small employers are at a higher-than-average risk of injury and illness. If construction safety and health is to make substantial progress, additional research and intervention for small employers is needed to help them implement more effective safety programs and practices (See recommendations 4, 6, and 10).

The Panel found that many of the significant intermediate outcomes involved equipment design. These included designs by NIOSH researchers, collaboration with other stakeholders, and changes to consensus standards, which subsequently led to redesigned equipment. Examples include the residential fall protection guardrail system; drilling devices to control silica, MSDs, and noise; anti-vibration PPE; and redesign of asphalt milling machines to control silica exposures. These types of engineering controls that eliminate or reduce hazardous exposures are widely recognized by safety and health professionals as the most effective type of hazard controls. Equipment design changes may be even more powerful when they are incorporated into consensus standards that affect equipment manufacturers, improving the safety of entire classes of equipment (See recommendation 7).

The Panel found that many of the significant intermediate outcomes involved changes to government standards, voluntary consensus standards, and other influential documents, including the Leadership in Energy and Environmental Design (LEED) criteria. The incorporation of effective safety measures in standards, codes, and systems affects many employers and manufacturers, and has great potential for impact (See recommendations 8 and 9).

The Panel found that many of the most significant intermediate outcomes grew out of partnerships with various organizations, including trade associations, unions, consensus standards committees, and governmental bodies. Impact examples include the asphalt milling machine project, masonry collaborations, consensus standards, and the fall prevention campaign. NIOSH’s impact is only achieved when its research and r2p efforts are translated and transmitted to the construction community through other parties. Continued efforts to find, maintain, and improve partnership opportunities is essential (See recommendation 9).

The Panel observed that the construction industry, like many industries, is changing rapidly, with advancements in artificial intelligence and robotics and a changing workforce (to name just a couple). To keep up with these advancements and address new safety and health concerns, horizon scanning and ongoing feedback from stakeholders is critical. The Panel appreciates the diverse reviews of the Construction Program, and encourages continuing feedback and review, including reviews on social media (See recommendation 10).

The Panel found that there is a great national need for NIOSH products to be interpreted into Spanish; translation into other languages may also be needed in specific areas of the country. NIOSH has published

Spanish versions of many of its documents and products, and should continue to do so. Translations into other languages can be prioritized with stakeholder input (See recommendations 2 and 4).

The Panel members recognized the value of safety and health surveillance, and the CPWR *Construction Chart Book* collection and presentation of this information. In the age of informatics and “big data,” new data sets are emerging that could help characterize the construction industry and safety conditions. One such data set is the database created by the OSHA Information System used to document OSHA’s voluntary and enforcement activities. NIOSH should be looking for new data sources, and should consider working with OSHA to improve and standardize the OSHA inspection database as a research and surveillance resource. The Panel also noted the data collection constraints posed by the Paperwork Reduction Act (PRA) clearance process. Expedited or blanket PRA approvals for surveys, focus groups, and other data collection efforts could improve the effectiveness of NIOSH research, surveillance, and evaluation efforts.

The Panel found that many of the most significant intermediate outcomes were achieved with many years of sustained effort (i.e., silica standard support, drill equipment, hand-arm vibration consensus standards). NIOSH and its researchers need to be persistent when working toward substantial, one-time impacts. NIOSH also needs to allocate some of its resources for investments in potential high-impact projects, even when future outcomes are remote and uncertain. The lengthy nature of many research projects may also indicate a need for succession planning efforts to ensure efforts in a promising subject area continue past the career of one researcher.

## Respirable Crystalline Silica

All five Panelists remarked that the NIOSH Construction Program provided strong support for OSHA’s silica rulemaking. Several Panelists believe the NIOSH research was instrumental in supporting the control methods and laboratory test method provisions of the standard. Specifically, the provisions of the standard that allow construction employers to comply by using specific control methods (29 CFR Part 1926.1153(c)(1), often referred to as Table 1)<sup>23</sup> would not have been possible without NIOSH research. The projected impact of the OSHA standard is expected to protect thousands of construction workers from this commonly encountered hazard.

The work to provide outreach and support to the industry as they implement silica controls will help improve adoption of preventive measures in the industry. The work on asphalt milling machines will protect thousands of workers, and is a model for protecting workers through equipment design and collaboration with industry partners. Partnerships with stone and masonry stakeholders provided recommendations and training in that industry. Several Panel members noted that the silica accomplishments are unusual, perhaps even unique, intermediate outcomes resulting from many years of prior research. Intermediate outcomes with this level of significance may be difficult to replicate for another health or safety issue in any given 10-year evaluation period. This highlights the need to be patient and persistent when waiting for substantial one-time impacts, as well as the need to invest in potential high-impact projects, even when future outcomes are remote and uncertain.

## MSD Prevention

All of the Panel members were impressed by the impact of the NIOSH Research on MSD reduction. Several noted the difficulties of influencing safety and health outcomes in a broadly defined area that encompasses many types of hazards, illnesses, activities, and equipment. Several Panelists believe the research and equipment design work for vertical and horizontal drilling equipment has the potential to provide significant protection from MSDs, silica exposure, and hearing loss, while increasing productivity and quality. The ability to

impact three hazards with one research and design effort is both efficient and effective, and NIOSH should seek out more of these multi-hazard opportunities.

One Panelist focused on hand-arm vibration research and the associated difficulty of convincing the industry to take action because of the focus on immediate safety risk and prevention of traumatic injury. He observed that hand-vibration hazards seem to be overlooked by most construction industry safety professionals, even though injury data show the relevance of this work.

The ability to collaborate with consensus standards bodies and manufacturers to improve tool and glove design will reduce exposure to hand-arm vibration and benefit the industry in the long run. Similarly, work on safe manual material handling and refining the NIOSH lifting equation will help prevent MSDs. Ongoing outreach to the construction industry, including guidance and advice for web pages and publications, will also help. The Panel also notes that there are many MSD hazards that need further attention, including whole body vibration and robotic material handling technologies. A gap analysis may be helpful when guiding future research in this area.

## Hearing Loss

The Panel members were impressed with the potential impact of NIOSH research on control of hazardous noise and construction worker hearing loss. As noted previously, hearing loss is a common problem in the construction industry. Like hand-arm vibration, the long-term effects of exposure to hazardous noise and other factors contributing to hearing loss are often under-recognized by construction employers and employees focused on traumatic injury prevention. The Buy Quiet initiative, power tool database, and noise measurement app have great impact potential for thousands of exposed workers. Ongoing and past research on impulse noise, ototoxic chemicals, equipment design, hearing loss measurement, and noise controls also have impact potential.

The recently published training materials, including noise/hearing loss training materials and OSHA 10- and 30-hour safety awareness trainings, have great potential for impact. The two OSHA trainings are required in several states and cities across the country. Even where they are not required, they are quite popular in the construction industry, and many employers require their employees and supervisors to take them. A common practice is to require 10-hour cards for workers and 30-hour cards for supervisors. In 2017, approximately 500,000 construction workers earned 10-hour cards and 150,000 received 30-hour cards.<sup>24</sup> If usage grows to a point where 10% receive the hearing protection training, 65,000 construction workers and supervisors per year could be positively influenced.

## Highway Work Zones

NIOSH research on highway work zones addresses serious safety hazards in an important segment of the industry. The topic also addresses a narrower range of hazards than the other four subject areas, highlighting the importance of targeted research topics. The work on blind-area diagrams, backover prevention, traffic control systems, proximity control technologies, and roadway safety consensus standards all have potential to improve safety for highway construction workers. Work with the Federal Highway Administration (FHWA) and the Roadway Safety Alliance highlight the power of partnerships and collaborations to improve safety and health. Additionally, work with the NIOSH Mining Safety and Health Research Program indicates a potential for NIOSH to form internal collaborations that may be helpful for other construction safety and health topics.

The Panel understands that NIOSH is reducing its investment in the highway work zone issue, and recognizes the need to reduce investments in one area to apply them to higher priority areas. Nevertheless, seeking out new

opportunities to make progress on this problem may be worthwhile, especially if they involve low-cost partnership efforts.

## Fall Prevention

The NIOSH research on fall prevention efforts addresses the leading cause of fatal traumatic injury to construction workers. Fatal falls have been one of the most difficult construction safety and health issues to impact, despite the existence of well-known solutions and decades-long efforts by many government agencies, associations, and private sector stakeholders. The most impactful intermediate outcomes were the OSHA revision of its general industry fall protection standards, revision of the American National Standards Institute's personal fall arrest system (PFAS) standards, and research underpinning the communication tower consensus standard, all of which are supported by NIOSH research. The NIOSH work on the fall prevention campaign (including the fall prevention stand-down), guidance and outreach products, web pages, videos, computer apps, training, equipment designs, fatality investigations, and PFAS advancements all have potential for impact, and work in these areas should continue.

During a major decline in the construction industry from 2008-2012, fall fatalities, both in number and rate, declined. Following this decline, from 2013-2016 (the most recent data), an increase in construction activity and the hiring of many new, young employees with limited training and experience led to an increase in the number of fall fatalities in the industry. The rate of fatal falls per 100,000 workers has also increased and is approaching pre-recession levels, indicating that the desired end outcomes have not yet been achieved.<sup>25</sup>

Consistent with the impressive quantity and quality of the 33 intermediate outcomes in this subject area, the Panel believes that this is not a failure of the NIOSH Construction Program. If not for NIOSH's efforts in this area, construction deaths and injuries due to falls would have increased even more dramatically. As one Panel member remarked, "The research that relates to slips, trips, and falls will assist and continue to educate the industry in an attempt to minimize hazards." The Panel believes that research and r2p efforts to prevent falls in construction should continue, and that NIOSH should consider applying additional resources to the issue. Research indicates that employees of smaller employers are more at risk of fall fatality, so efforts to reach smaller employers more effectively could be useful in this effort.

## Recommendations for the Future

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Based on its observations and findings, the Panel offers 11 recommendations for the NIOSH Construction Program to consider as it moves forward.

1. Consistent with its finding that the NIOSH Construction Program is highly relevant and impactful, the Panel recommends that NIOSH continue to conduct basic and applied research to improve construction worker health and safety. The effort should focus on prioritizing research in areas where improvement is most needed and maintaining a pipeline of research findings and developments for transfer and implementation. It is important to note that some topics require significant time to reach fruition.
2. The Panel recommends that NIOSH increase its efforts to improve r2p dissemination and outreach efforts to make the construction industry, construction workers, and construction safety and health personnel more aware of the NIOSH Construction Program and the NIOSH products that could help improve safety and health at construction sites.
3. The Panel recommends that NIOSH focus on developing software products (applications, interactive web pages, virtual reality learning, etc.) to provide the construction industry safety and health tools that use technology and algorithms, allowing large numbers of construction employers, employees, and safety professionals to get construction safety assistance when needed. Review of existing products may provide insight into best practices for software design; input from construction stakeholders may help identify products with greater potential for impact.
4. The Panel recommends that NIOSH perform research on the most effective methods to communicate and interact with small construction employers. The research would investigate methods for finding small employers, reaching them quickly, and motivating them to implement safety measures. This may be used to support awareness projects, marketing activities, and other r2p efforts. Research on the motivations of small employers who are successfully managing safety and health may be beneficial.
5. The Panel recommends that NIOSH perform research on the best approaches to train and educate construction employers, workers, and safety professionals. These efforts should focus on methods that are effective with adult learners, non-English-speaking learners, and low-literacy audiences. Micro-learning, online training, and the use of augmented, virtual, and immersive reality should also be topics of research.
6. The Panel recommends that NIOSH perform research to investigate effective methods that help employers develop safety and health programs. NIOSH should investigate effective methods to help move them from a point of low safety and health performance to a point of compliance with government regulations, and then to adoption of best practices.
7. The Panel recommends that NIOSH continue to prioritize research that results in new and improved construction equipment that protects workers from hazards. NIOSH should work with consensus standards bodies to incorporate safer equipment designs into requirements that improve equipment used across the construction industry.
8. The Panel recommends that NIOSH continue to prioritize research and r2p efforts that result in safer mandatory government standards, voluntary consensus standards, and other influential documents, such as LEED and building codes, both in the United States and internationally.

9. The Panel recommends that NIOSH build on recent successes with partnerships to develop powerful relationships that improve construction safety and health. Relationship development should be focused toward groups that will use their own resources, intellectual capital, ideas, and spheres of influence to improve safety and health. NIOSH and the NCC should maintain the helpful existing relationships they have established, as well as seek out stronger relationships with other groups, such as trade associations, professional associations, and owners. Partnerships with large construction companies and their trade associations may provide an opportunity to speed adoption of new products and technologies.
10. The Panel recommends that NIOSH improve its efforts to evaluate and capitalize on the productivity effects of its research and recommendations. One example is found in the development of new or improved equipment, which may have positive effects on workplace productivity. Potential improvements to safety and health, combined with improved productivity, should be used in r2p efforts to motivate and encourage employers to adopt safer practices.
11. The Panel recommends more frequent reviews of projects within the Program (especially for the most rapidly developing areas), including ongoing informal feedback from stakeholders. The precise mechanisms are less important than early, frequent, and diverse feedback by affected stakeholders, especially for topics that are rapidly evolving. With the ongoing development of online tools for collecting information and facilitating remote collaboration, future stakeholder input processes could be improved even further.

## Appendix 1 – Acronyms

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BSC	Board of Scientific Counselors
CDC	Centers for Disease Control and Prevention
CPWR	The Center for Construction Research and Training
DAFW	Days Away From Work
FHWA	Federal Highway Administration
GPRA	Government Performance and Results Act
HAVS	Hand-Arm Vibration Syndrome
LEED	Leadership in Energy and Environmental Design
MSD	Musculoskeletal Disorder
NCC	National Construction Center
NIHL	Noise-Induced Hearing Loss
NIOSH	National Institute for Occupational Safety and Health
NORA	National Occupational Research Agenda
OSHA	Occupational Safety and Health Administration
PFAS	Personal Fall Arrest System
PPE	Personal Protective Equipment
r2p	Research to Practice
RCS	Respirable Crystalline Silica

## Appendix 2 – Summary Panel Scoresheet

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### NIOSH Construction Program Review Panel Scoresheet

#### Relevance Scores

**5.0 = Average Panel Relevance Score**

#### Relevance Scoring Rubric

- 5** = The rationale for the activities completed by the program are highly justified.
- 4** = The rationale for the activities completed by the program are justified.
- 3** = The rationale for the activities completed by the program are moderately justified.
- 2** = The rationale for the activities completed by the program are minimally justified.
- 1** = The rationale for the activities completed by the program are not justified.

#### Impact Scores

**4.5 = Average Panel Impact Score**

#### Impact Scoring Rubric

- 5** = Research program has made major contribution(s) to worker health and safety on the basis of end outcomes or well-accepted intermediate outcomes.
- 4** = Research program has made some contributions and/or demonstrates great potential to contribute 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 safety and health. Well-accepted outcomes have not been recorded, but potential for well-accepted outcomes has been demonstrated.
- 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, and the potential for well-accepted outcomes is limited.
- 1** = Research activities and outputs do not result in, or are not likely to have, any application.

#### Total Score

**5.0 (Average Panel Relevance Score) + 4.5 (Average Panel Impact Score) = Total Program Score**

**9.5 = Total NIOSH Construction Program Score**

## Appendix 3 - References

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1. IOM (Institute of Medicine and National Research Council) [2009]. *Evaluating occupational safety and health research programs: Framework and next steps*. Washington, DC: The National Academies Press.  
<http://nationalacademies.org/hmd/Activities/Research/NIOSHResearch.aspx>
2. National Research Council (U.S.) and Institute of Medicine (U.S.) Committee to Review the NIOSH Construction Research Program [2009]. *Construction research at NIOSH: Reviews of research programs of the National Institute for Occupational Safety and Health*. Washington, DC: National Academies Press.  
<https://www.nap.edu/catalog/12530/construction-research-at-niosh-reviews-of-research-programs-of-the>.
3. NIOSH [2009]. NIOSH Construction Program Plan to Implement the National Academies' Program Evaluation Recommendations, NIOSH Board of Scientific Counselors Review.
4. NIOSH [2014]. *NIOSH Construction Research Program Implementation of the National Academies' Program Evaluation Recommendations: A report to the NIOSH Board of Scientific Counselors*. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. <https://www.cdc.gov/niosh/nas/pdfs/con-na-2014-update.pdf>.
5. NORA Construction Sector Council [2008]. *National Construction Agenda for Occupational Safety and Health Research and Practice in the U.S. Construction Sector*.  
<file:///C:/Users/jmadd/Documents/niosh%20construction%20program%20review%202018/Resources,%20NIOSH%20%20review/NORA%20Construction%20agenda%20Oct%202008.pdf>.
6. NORA Construction Sector Council [2013]. *Mid-decade review: Supplement to the National Construction Agenda, National Occupational Research Agenda (NORA)*. Washington, DC: Construction Sector Council.  
[https://www.cdc.gov/niosh/nora/comment/agendas/construction/pdfs/const\\_middecadereview\\_oct2013.pdf](https://www.cdc.gov/niosh/nora/comment/agendas/construction/pdfs/const_middecadereview_oct2013.pdf).
7. NIOSH [2017]. *National Occupational Research Agenda: Second decade in review*. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2017-146.  
<https://www.cdc.gov/niosh/docs/2017-146/pdfs/2017-146.pdf>.
8. *National Occupational Research Agenda: NIOSH sector and cross-sector program supplement, 2006–2016*. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2017-147.  
<https://www.cdc.gov/niosh/docs/2017-147/default.html>.
9. *National Occupational Research Agenda for Construction*.  
<https://www.cdc.gov/nora/councils/const/agenda.html>

10. Mayne J. [2001]. Addressing attribution through contribution analysis: Using performance measures sensibly. *Can J Program Eval.* 16(1):1-24.
11. Mayne J. [2011]. Contribution analysis: Addressing cause and effect. In: Forss K, Marra M, and Schwartz R, Eds. *Evaluating the Complex: Attribution, contribution, and beyond*. New Brunswick: Transaction Publishers.
12. Morton, S. [2015]. Progressing research impact assessment: A ‘contributions’ approach. *Rsrch Eval.* 24(4):405-419.
13. NIOSH [2018]. *NIOSH Construction Program: Evidence Package for 2007-2017, April 2018.*  
<https://www.cdc.gov/niosh/programs/review/default.html>
14. OSHA [2016]. Occupational exposure to respirable crystalline silica. Final rule. 29 CFR Parts 1910, 1915, and 1926. [Docket No. OSHA–2010–0034]. RIN 1218–AB70. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration.  
<https://www.osha.gov/laws-regs/federalregister/2016-03-25-1>
15. BLS [2017]. *2016 Survey of Occupational Injuries & Illnesses Chart Package.*  
<https://www.bls.gov/iif/osch0060.pdf>
16. BLS [2017]. Table 2. *Numbers of nonfatal occupational injuries and illnesses by industry and case types, 2016.*  
[https://www.bls.gov/iif/oshsum.htm#16Summary\\_Tables](https://www.bls.gov/iif/oshsum.htm#16Summary_Tables)
17. Tak S, Davis RR, Calvert GM [2009]. Exposure to hazardous workplace noise and use of hearing protection devices among US workers—NHANES, 1999–2004. *Am J Ind Med.* 52(5):358–371.
18. Masterson EA, Deddens JA, Themann CL, Bertke S, Calvert GM [2015]. Trends in worker hearing loss by industry sector, 1981–2010. *Am J Ind Med.* 58(4):392–401.
19. Masterson EA, Bushnell PT, Themann CL, Morata TC. [2016]. Hearing impairment among noise-exposed workers—United States, 2003–2012. *MMWR Morb Mortal Wkly Rep.* 65(15):389–394.
20. FHWA [2018]. *Traffic crashes in work zones: Work zone fatalities by year and state - annual tables, 1982–2014.* Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration  
<https://www.workzonesafety.org/crash-information/work-zone-fatal-crashes-fatalities/#national>.
21. BLS [2018]. *Fatal occupational injuries at road construction sites, 2003–2015.* Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics.  
[https://www.workzonesafety.org/files/documents/crash\\_data/2003-2016\\_worker\\_fatalities.pdf](https://www.workzonesafety.org/files/documents/crash_data/2003-2016_worker_fatalities.pdf).
22. CPWR [2018] *The Construction Chart Book - The U.S. Construction Industry and Its Workers*, Sixth Edition; CPWR.com.  
<https://www.cpwr.com/publications/research-findings-articles/construction-chart-book>.

23. OSHA, 2018, OSHA respirable crystalline silica standard, 29 CFR Part 1926.1153.  
[https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=1270](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=1270).
24. OSHA, 2018. Extracted from OSHA outreach training web pages.  
[https://www.osha.gov/dte/outreach/outreach\\_growth.html](https://www.osha.gov/dte/outreach/outreach_growth.html)  
[https://www.osha.gov/dte/outreach/outreach\\_growth.html](https://www.osha.gov/dte/outreach/outreach_growth.html)
25. BLS [2017], TABLE A-9. Fatal occupational injuries by event or exposure for all fatal injuries and major private industry sector, all United States, 2016; U.S. Department of Labor, Bureau of Labor Statistics.  
<https://www.bls.gov/iif/oshcfoi1.htm>.