


Translation research in occupational safety and health: A proposed framework

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Translation research in occupational safety and health is the application of scientific investigative approaches to study how the outputs of basic and applied research can be effectively translated into practice and have an impact. This includes the study of the ways in which useful knowledge and interventions are disseminated, adopted, implemented, and institutionalized. In this paper, a 4-stage framework (Development, Testing, Institutionalization, and Evaluation) is presented. Translation research can be used to enhance the use and impact of occupational safety and health knowledge and interventions to protect workers. This type of research has not received much attention in the occupational safety and health field. However, in contemporary society, it is critical to know how to make an impact with the findings and outputs of basic and applied research. This paper provides a novel framework for consideration of how to advance and prioritize translation research for occupational safety and health.

KEYWORDS

dissemination, intervention, research-to-practice

1 | INTRODUCTION

The occupational safety and health (OSH) research field historically has focused more on the etiologic end of the research-to-practice (r2p) continuum than on the implementation and impact end.^{1–4} This also has been the case in medicine and public health fields.^{5–7} There has been a call to increase efforts to investigate factors that enhance or limit the development, transfer, and use of OSH risk factor and

intervention information and technology, thus ensuring that these outputs lead to improvements in worker health.^{1–4,8–13}

There is an extensive amount of OSH research and developed knowledge that is not applied. For example, much is known about the cause and prevention of occupational hearing loss, but it is still one of the most prevalent occupational illnesses.¹⁴ Similarly, workers are still exposed to lead, one of the oldest known toxicants, at levels much higher than recommended.¹⁵ The list of known but uncontrolled or inappropriately controlled hazards is long and growing, even though risk management techniques are known.^{16–18} Consequently, there is value in studying factors that influence the uptake and use of new and extant research findings.

The purpose of this paper is to develop a framework, or basic conceptual structure, for the consideration and promotion of translation research in the OSH field. The framework could be used by OSH organizations, defined here to include academics, government agencies, trade associations, unions, insurers and NGOs (nongovernmental organizations) to consider, conduct, and benefit from translation research. Although the components of this framework are not novel, their adaptation for OSH research is a new and needed perspective.

1.1 | Foundation, scope, and nomenclature for translation research

The subject of translation research is the nature and drivers of translation processes and barriers to them. Translation research encompasses the scientific study of factors that optimize closing the gap between new or extant research findings and guidance, and real-work practices, outcomes, and impacts in the workplace (Figure 1). As such, translation research has three aspects: it is a set of methodologies, a body of substantive scientific knowledge, and a perspective for viewing a continuum of research efforts from the identification of hazard and risks, through intervention to impact.^{6,7,19–35}

Translation research is a multidisciplinary field of research composed of such disciplines as intervention effectiveness research,^{9,36} implementation research,^{5,37} health communication, and

dissemination research,^{38–42} evaluation research,¹²⁶ knowledge utilization,^{9,24,36,41,43,44} diffusion of innovations research,^{38–40} social marketing and commercial marketing,^{40,45,46} and surveillance and economic evaluation.^{47–52} However, application of these and related approaches in the OSH field has been limited and as Rantanen¹ has noted, “such research on research is relatively scarce and even the paradigm for such studies is not well developed.”

Quite often the phrase “translation research” has been used to describe the systematic effort to convert basic research outputs into practical applications to enhance human health and well-being.⁵³ As such it is frequently referred to as “translational research” or “translational science.”⁵⁴ Various journals or programs refer to the term “translational” in the title (eg, American Journal of Translational Research), and the National Institutes of Health (NIH) has the National Center for Advancing Translational Sciences. Generally, these uses of the phrase translational research refer to harnessing knowledge from basic medical science to bring it to clinical practice (so called bench-to-bedside models). In contrast, we define the phrase “translation research” to refer to the study of the process of moving “research-to-practice-to-impact” and the methods, barriers and facilitators and context (social, political, organizational, etc.) encountered in this process.⁵⁵ However it should be noted that in the literature the two descriptors of research (translation and translational) overlap.⁵⁶ In this article, we use “translation research” generally to refer to the study of the processes that move research/

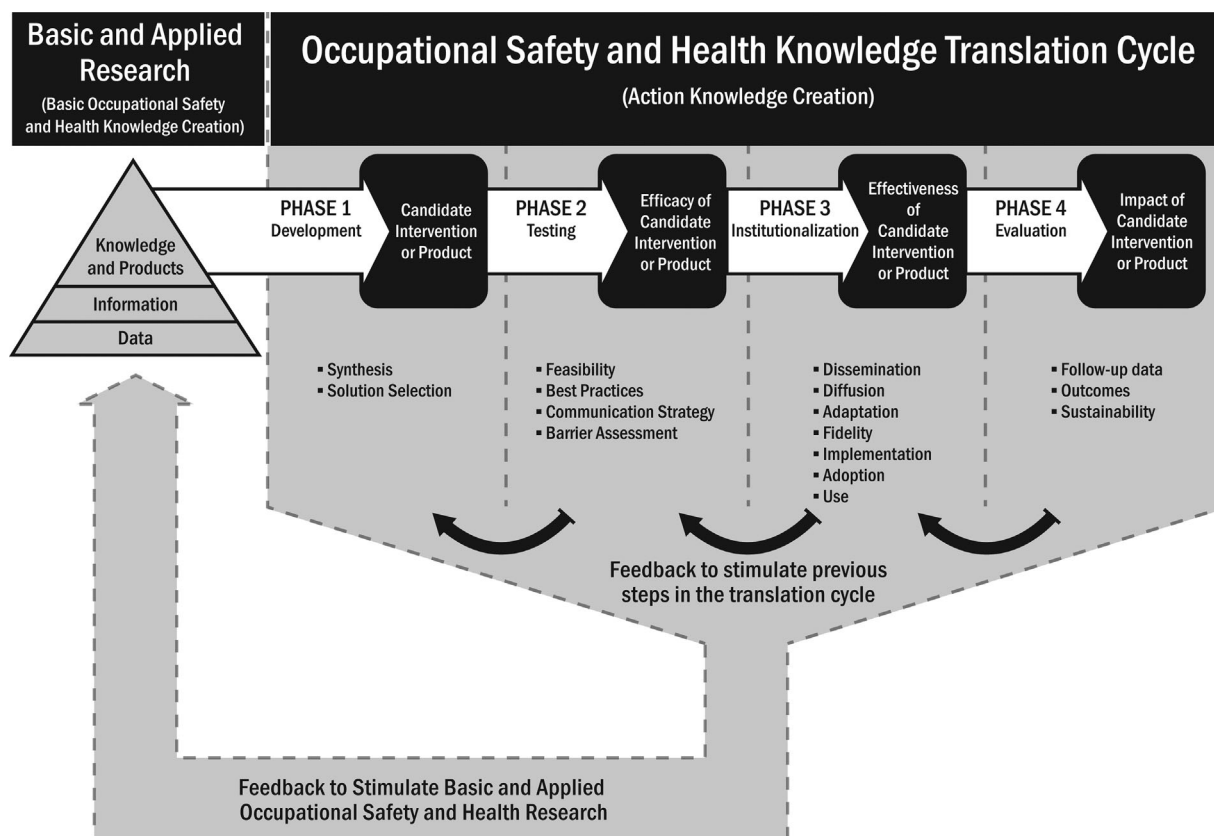


FIGURE 1 Conceptual framework for translation research in occupational safety and health

innovations from adoption, to implementation to maintenance/institutionalization in the workplace.

1.2 | Adaptation to the OSH field

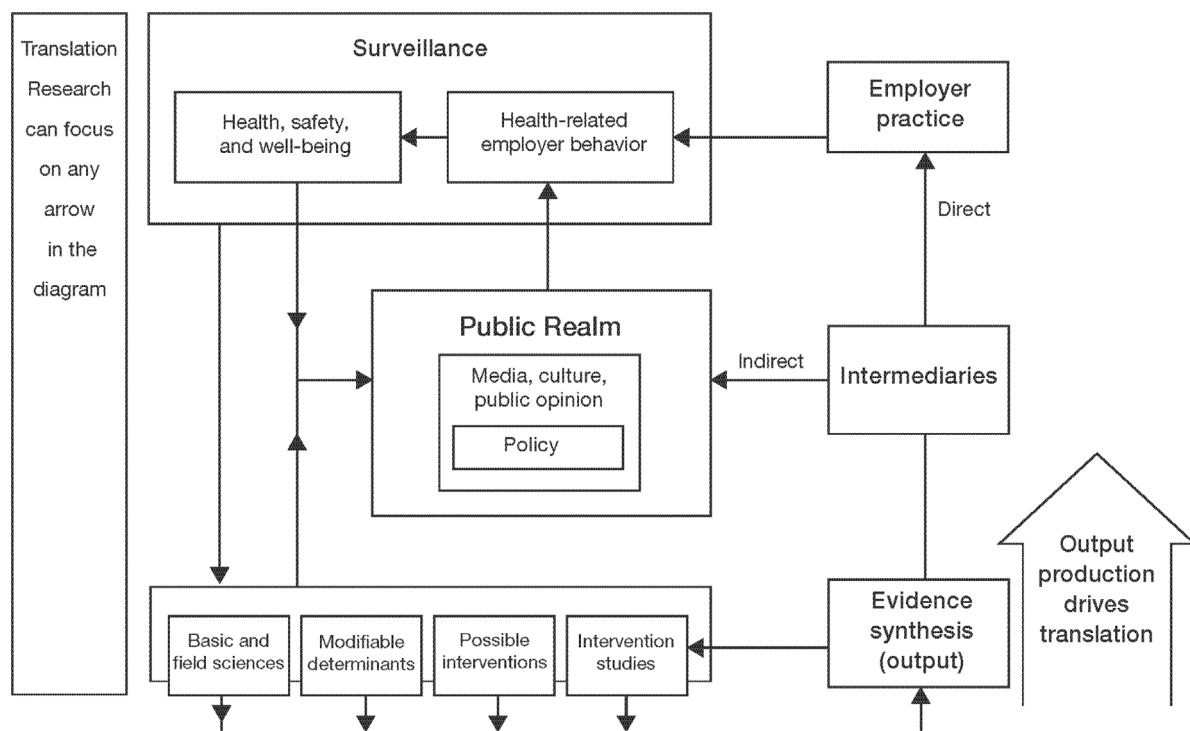
The translational model (bench to bedside) for clinical medicine may be adapted to the OSH field.^{5,21,23,25,28,36,43,44,57–60} The objectives of using this translational model are to identify important basic or etiologic findings and subsequent interventions and to study how they can best be applied to address workers' occupational safety and health.

Additionally, there may be a need to consider iterative and bidirectional processes, which are integral to OSH translation. This need to consider iterative processes has been captured conceptually in a translation research model for public health developed by Ogilvie et al, which provides an integral role for surveillance in assessing impact and identifying modifiable determinants.²⁵

Translation research in OSH is envisioned to be theory-based and model-based, drawing on the demand and control model,⁶¹ health belief model⁶² the transtheoretical model of change,⁴⁰ Precede-Proceed model,⁶³ health promotion model,⁶⁴ and social cognitive theory,⁶⁵ among others. Such research can occur at any of the connecting arrows in Figure 2. We have modified Figure 2 to include employers and intermediaries, so that it also connotes that there are many stakeholders (ie, employers, business owners, labor organizations, resource managers) in OSH with differing agendas and concerns.

Taking into account the strengths of the clinical and public health models, we propose a framework (shown in Figure 1 and Table 1) for translation research for the OSH field that encompasses adaptations of the four traditional stages of translation research to optimize the development and dissemination of research outputs in ways that motivate target audiences concerned with worker health and safety to adopt, implement, and sustain change to improve workplace safety and health.^{30,89} This framework (Figure 1, Table 1) builds on the NIH model,^{90,91} interpreted by Khoury et al,²³ as well as the Noonan and Emshoff model,⁵⁵ the public health model of Ogilvie et al,²⁵ Knowledge to Action (KTA) and Knowledge Transfer and Exchange (KTE) models,^{90,92,93} and the extensive portrayal of OSH translation research in the commercial fishing industry by Lucas et al.⁶⁰ The framework utilizes a linear pathway from underlying basic or applied OSH information and knowledge to impact, with a continuous cycle of feedback loops to stimulate research at all points along the pathway. A linear pathway is used to represent a holistic view of the potential intended direction from each translation research stage and the underlying risk being reduced (eg, hearing loss, musculoskeletal disorders, respiratory disease) to the final eradication or control of that risk (ie, reductions in mortality, morbidity, and injury).

The framework utilizes a variety of different disciplines and approaches to learn how best to put research into practice. Translation research efforts can now close the gap between basic and applied research outputs and OSH impact by studying the best ways that validated candidate interventions, research findings, and



Adapted from Ogilvie et. al. (2009)

FIGURE 2 Critical focus points for translation research in occupational safety and health

TABLE 1 Examples of translation research for different types of hazards

Physical agent: noise-induced hearing loss			
Stage		Description	Reference
0 ^a	Hazard/Problem Identification	Occupational noise-induced hearing loss	Dobie ⁶⁶ ; Hager ⁶⁷
1	Development	Development of protocol for testing hearing protection devices	Berger et al ⁶⁸
2	Testing	Hearing protector effectiveness study	Morata ⁶⁹ ; Murphy et al ⁷⁰
3	Institutionalization	Identifying attitude and behaviors associated with wearing hearing protection	Stephenson and Stephenson ⁷¹ ; Bocksteel et al ⁷²
4	Evaluation	Impact of hearing conservation on incidence of hearing loss	Davies, et al ⁷³ ; Masterson et al ¹⁴
Hazardous substance: silicosis in mining			
0	Hazard/problem identification	Identification of silicosis in mining	Wagner ⁷⁴
1	Development	Development of an intervention	Cecala and O'Brien ⁷⁵
2	Testing	Testing worker response to intervention	Haas et al ⁷⁶
3	Institutionalization	Development of guidelines for widespread use	Reed et al ⁷⁷
4	Evaluation	Utilization of on-going or new surveillance data to determine impact	Need studies of use of interventions, studies of silicosis prevalence, incidence, mortality
Psychosocial hazard: stress			
0	Hazard/problem identification	Identification of stress hazards in healthcare workers	Bourbonnais et al ⁷⁸
1	Development	Development of interventions in healthcare	Bourbonnais et al ⁷⁹
2	Testing	Testing the effects of modifying the psychosocial work environment	Jimmieson et al ⁸⁰
3	Institutionalization	Systematic review of effectiveness of various interventions	Ruotsalainen et al ⁸¹
4	Evaluation	Surveillance	Dollard et al ⁸²
Safety hazard: Winch entanglements resulting in severe traumatic injuries and fatalities			
0	Hazard/problem identification	Identification of injuries involving winches	NIOSH ⁸³
1	Development	Development of an auxiliary stopping switch	Lincoln et al ⁸⁴ ; Lincoln et al ⁸⁵
2	Testing	Testing interventions in target users	Levin et al., ⁸⁶ ; Lincoln et al ⁸⁵
3	Institutionalization	Examining methods of implementation	Teske and Victoroff ⁸⁷
4	Evaluation	Surveillance of injuries	National Institute for Occupational Safety and Health (NIOSH) ⁸⁸

0^a Stage 0 is the basic or applied research finding that becomes the focus for study in stages 1–4 of the translation research framework. It is not part of that framework.

authoritative recommendations can systematically and sustainably be moved to adoption in ways that address workplace health and safety problems.

1.3 | Objectives of translation research for occupational safety and health

There are two proposed objectives of the framework for translation research. The first is to develop generalizable knowledge related to the research-to-practice continuum for the OSH field. The second is to apply this generalizable knowledge whenever possible to provide

feedback to organizations that develop or use OSH information (ie, OSH organizations) and investigators to improve their efforts.

Important translation research should include studies that:

- Examine how best to facilitate and optimize awareness among key audiences of OSH organizations' activities and outputs^{94–95};
- Investigate methods to improve decision makers' (eg, employers) ability to act upon authoritative recommendations and guidance (research-to-practice);
- Increase researchers' responsiveness to and collaboration with stakeholders (eg, employers and workers), so that the information

and advice end users receive fit their needs, priorities, and circumstances (practice-to-research)⁶³;

- Explore what motivates partners, stakeholders, and intermediaries to more effectively seek, model, and communicate credible OSH organizations' recommendations and guidance to others;
- Identify barriers as well as solutions for overcoming these barriers in political, social, and economic systems that inhibit the translation of practices or technologies into the workplace;
- Assess readiness of the target audience to receive this guidance, and shed light on the factors that facilitate or hinder adoption decisions.^{38,39,96}
- Evaluate the implementation of evidence-based programs, including whether and how they are implemented with fidelity (ie, as designed) and adaptations made to the original program.
- Assess the impact of interventions and practices on workers' morbidity, mortality, and well-being.

1.4 | Framework for translation research in the occupational safety and health field

Levels of implementation of research findings, technological innovations, and recommendations, as well as guidance focused on worker health and safety, remain suboptimal across many industrial sectors.^{3,15,97} Information is necessary, but insufficient, for facilitating behavior change in the workplace,⁹⁸ and it is known that simply sharing knowledge about new discoveries on websites, publishing and disseminating technical reports and journal articles, and presenting at conferences is inadequate to change OSH investment and practice on a large scale.^{2,99} Therefore, for promising practices to be enacted on a large-scale, it is critical to explore the characteristics of an innovation, the characteristics of an adopting organization (and the individuals within that organization), and their interactions that predict the uptake and maintenance of that innovation.^{38,55,96,100} Without a stronger focus on translation research, the OSH field may continue the processes of knowledge creation without adequate attention to what creates effective uptake of research outputs and how to best execute the translation process.

The framework for translation research in OSH proposed here was developed by an internal NIOSH workgroup with expertise in such fields as intervention effectiveness research, implementation science, communication and diffusion research, program evaluation, and impact evaluation among others. The NIOSH workgroup surveyed the relevant literature on translation research frameworks and adapted the existing NIH framework to include elements of other frameworks including the KTA,⁹² and Noonan and Emshoff models,⁵⁵ the KTE approach of Lavis et al²⁰ and Estabrooks and Glasgow,¹⁰¹ and the interpretation by Lucas et al.⁶⁰

As stated earlier, an objective of applying these research efforts to the outcome end of the research-to-practice continuum is to develop relevant, generalizable, and specific knowledge on how to obtain optimal impact of research outputs. Common challenges in pursuing this objective includes: (1) Defining subcategories of intermediate and end outcomes; (2) Studying how decision-makers (employers, insurers,

government agencies) get and use OSH information and the barriers they encounter; and (3) Identifying which approaches work and do not work in achieving impact of OSH research outputs. This framework requires the development of a comprehensive OSH research agenda focused on high-priority translation research goals.

2 | FOUR STAGES OF TRANSLATION RESEARCH IN OSH

A prerequisite for effective translation research in OSH is to take a holistic view of the potential pathway from each OSH basic research result to reduction of underlying OSH risk to the final eradication or control of that problem. Within that pathway, it is possible to conceptualize four stages of translation research. The pathway is multidimensional in that each stage of translation research may not lead specifically to the next stage but may provide useful information for practitioners of r2p to construct and implement impact-generating efforts and practices. Translation research is intentionally portrayed with linear models because it is goal oriented. Thus each study at each stage needs to be viewed as part of a continuum of efforts to reach the goal of reduced burden of the hazard or problem identified. This linear view does not preclude extensive feedback to various prior stages but the overall direction is toward a goal of reducing a specific risk. Table 1 shows examples of the four stages (Development, Testing, Institutionalization, and Evaluation) of research for four different types of hazards. Prior to the four stages, is stage 0 (referred to in Table 1 as Hazard/Problem Identification), which is the performance of basic and applied research that leads to the identification of hazards and risks, or to the indication of a solution or intervention that is needed or could be developed.

2.1 | Stage 1: Development

This initial stage is the assessment of technology, equipment, program designs, measures, or analyses needed to develop interventions from, or applications of, basic research.²² Here, the subject of study is the first step in moving the outputs of OSH research into a trialable prototype or program. For example, in seeking a solution to the problem of the inability to measure effectiveness of hearing protection as it is used on worksites, NIOSH scientists created and tested within their laboratories a laptop-based system capable of conducting onsite fit testing of hearing protection.¹⁰² They then created a candidate, potentially marketable, invention that employers could use to gather information about the effectiveness of the hearing protection being used by their workforce in real time. Small pilot testing on a limited "proof of concept" basis occurred at this stage, to inform the process of refining a marketable invention derived from laboratory-based knowledge of hearing protection effectiveness measurement. Reports were published in the peer-reviewed literature and presented at key conferences.¹⁰³ Developing marketable interventions requires obtaining feedback from potential users of the interventions as well as evaluating economic, social, and cultural appeal. Many, if not most,

OSH researchers currently address workplace health and safety hazards through this level of research. Another example is the development of the NIOSH ladder safety application (app) for smartphones,¹⁰⁴ which has subsequently become the subject of stage 2 and 3 translation research efforts.

Additionally, related training and health communication research occurs in the OSH field complementary to this stage and can be thought of as developmental, assessing the options for audience segmentation, channels of dissemination, message design, forms of delivery of messages, or usability studies before technology is finalized.^{4,99,105}

Researchers may conduct studies that result in the production of health communication products in a variety of formats (written, web, video, social media). There are still many research gaps relating to the investigation of factors that affect how research findings can be optimally “written” and presented in a variety of formats and messages to motivate policy makers, OSH professionals, and decision makers (including workers and employers) in businesses.

Stage 1 translation research supports and informs the scaling up of basic research outputs toward efficacy research in stage 2. This work could also resolve critical translation research questions related to optimal “dosage” of interventions. Other activities include developing options for the packaging, transmission, and dissemination of workplace OSH guidance and interventions.

For example, NIOSH produces significant model training programs and products that are typically turned over to study partners on a small scale or published for distribution on a website. Training research that identifies and investigates gaps in knowledge associated with refresher training is needed to improve evidence-based guidance about the frequency, level of engagement, and modality of training methods. Similarly, all industries are utilizing online training as a way to impart knowledge, but there is a gap in the understanding of factors critical to effective online training. Research on transfer of training is an example of translation research.¹⁰⁵

Laboratory-based translation research is by definition generally at the stage 1 level although other stages may come into play over time. Critical issues to consider in stage 1 translation research include: What are the greatest needs within the OSH organization to assist laboratory investigators in moving their discoveries and recommendations out of the laboratory? Can OSH organizations identify promising solutions bogged down in stage 1 or clearly ready for a stage 2 trial?

2.2 | Stage 2: Testing

This second stage should capture and analyze evidence-based success stories, including case studies, pilot work, and small intervention studies that can be scalable into stage 3 intervention effectiveness trials. There is a persistent need in OSH research to document, validate, replicate, and/or generalize isolated OSH successes to gather evidence needed to justify a stage 3 large scale effort. Research at this level should involve significant interaction between researchers and users leading to exchanges of information, synthesis of evidence, and dialogue with key partners about feasibility of recommendations, including cost benefit analyses on a local scale.

Stage 2 research assesses the efficacy and potential value of a new finding, invention, process, training program, or intervention for larger scale OSH application or practice to a targeted work sector, or for a targeted health outcome across sectors. Thus testing stage research seeks to assess the internal validity of the research by examining whether the promising laboratory or pilot effort is effective in the workplace. The goal of this step is to gather formal evidence that a new process, training program, workplace intervention, authoritative recommendation, or technology can be feasibly utilized in an effective manner with a targeted workplace or workplaces. In other words, it serves as an experimental opportunity to assess the potential future impact of large-scale utilization of the program or process.

For example, a current NIOSH translation research study is focusing on a major employer to test a new approach to training temporary workers before their placement on job sites. Another study is exploring work with insurers to test a new mobile phone application designed to provide on-worksites guidance to safe work practices for addressing common hazards in residential construction. Outputs at this level may include peer-reviewed publications and government reports, training products, or technology ready for widespread use. Stage 2 research may also focus on enablers, barriers to action, and the characteristics of the innovation and the adopting organization which may inform efforts to scale up the intervention. Similarly, research in OSH is needed to shed light on the predictors of effective program implementation. As Fixsen et al, point out in their extensive review, implementing a program effectively is as important as implementing an effective program. A more detailed discussion of these points is provided under stage 3 below.⁵

Most OSH field intervention, training, and outreach studies completed in the past could be considered as stage 2 translation research. Most have been conducted on a limited basis with an industry partner, at a few companies, or with limited workplace samples. Typically, results from those studies are published in the peer-reviewed literature and perhaps products are handed off to participating partners, but with that, the OSH research organization efforts usually end. There is a need for further research emphasis and activity beyond the publication stage. Translation research fills this gap. Translation researchers should convene periodically to identify those successful (eg, published evidence-based) small scale studies that warrant scaling up to a nationwide or industry-wide intervention and that serve as potential process models. When promising interventions are noted, prioritized funding could be utilized to move them into stage 3 studies.

2.3 | Stage 3: Institutionalization

The third stage of the translation research framework involves studies of evidence-based technology and recommendations into well accepted OSH practice, through large-scale delivery, dissemination, and diffusion research.^{17,28,47,60,106,107} The emphasis now is on *external validity*, resolving implementation challenges, and ensuring that an intervention or recommendation actually works within and can be integrated into a broad range of workplace settings. It should be

noted that, although internal validity criteria are important for measuring translation research outcomes, studies specifically designed to maximize external validity and that provide estimates of the effectiveness of an intervention across target populations, cultural contexts, delivery agents, and modalities are currently limited and more are needed to expand the public health evidence base.^{7,63,108,109} Studies at this stage involve identifying methods for overcoming diffusion and utilization obstacles and opening channels to ensure OSH products and guidance are integrated and utilized in a sustainable way by targeted industries on a sector or national scale. In this stage, smaller successful interventions validated through stage 2 studies may be scaled up so that they reach all or nearly all targeted workers.

2.3.1 | Uptake

Research is needed in the OSH field related to why and how new programs, practices and policies are taken up by stakeholders. Scientific support for the effectiveness of an intervention is just one of a set of perceived attributes that can affect adoption decisions.³⁹ When considering uptake of innovations, business enterprises engage in a complex cost-benefit analysis as to the risk and advantages of change. Stakeholders may prioritize factors such as compatibility with existing programs, cost-effectiveness, the values of individuals within the organization and the culture of the organization, and relative advantage over other programs when making adoption decisions.^{38,109} Furthermore, as Weiner points out, organizational readiness for change must be gauged to determine the extent to which employers and employees within organizations are “psychologically and behaviorally” prepared to make the changes in policies, practices and processes that are necessary to enact an innovation and to support its on-going use.⁹⁶

Once innovative OSH programs are put into place, translation research is needed to understand the factors that lead to successful implementation of innovations. As Durlak and DuPre³⁷ note in their extensive review of nearly 500 non-occupational implementation studies, the magnitude of mean effect sizes are at least two to three times higher when programs are carefully implemented than when implementation is incomplete or unsuccessful. The fidelity of program implementation is also a critical aspect for exploration, and one that is not often a focus of OSH research. The concept of fidelity, sometimes called adherence, integrity, or program “dosage,” is a determination of how well a program is delivered as it was designed (and tested in the efficacy stage).¹¹⁰ Durlak and DuPre reported evidence from 59 quantitative studies confirming that higher levels of implementation are in general associated with better outcomes, particularly when fidelity or dosage is assessed.³⁷

By necessity, work at this level involves working with intermediaries already serving targeted employers, workers, and workplaces to understand their motivation to engage in new or additional OSH activities and finding ways to integrate new knowledge or technology into their existing programs and practices in a sustainable manner. Very little OSH work has been conducted at stages 3 and 4.^{28,89,107,111} One stage 3 example is a NIOSH partnership with the Mexican consulates and Mexican Ministry of Health to integrate information and guidance about

OSH into all of their consulate educational programs.^{112,113} While initial work (stage 2) was conducted in several consulates to test and fine tune messages and approach, scaled up interventions and guidance (stage 3) have involved all 50 consulates with the goal of reaching all Mexican immigrants served by those consulates with basic OSH information.

2.3.2 | Barrier assessments

Across multiple domains of OSH research, barrier assessments are a critical focus for stage 3 translation research (as well as stage 2 translation research). Common barriers such as lack of reporting on moderating variables or lack of evidence of sustainability are reported in the medical translation research literature and related to health education and health promotion programs.^{7,22} This literature may provide indications of external barriers preventing OSH translation as well. There is a need to assess and document barriers to and facilitators of institutionalizing and sustaining new recommendations, training, or technology leading to generalizable knowledge that in time should measurably improve the health and safety of workers.

Thus investigations should be developed to look at OSH professional provider motivation/behavior and attitudes; factors affecting gatekeepers of information (employers, unions, service providers, suppliers) and new work practices; organizational structures that either encourage or discourage change; adequacy and usability of information systems; lack of incentives or strong disincentives; key decision makers; and financial barriers.^{11,20,34,47,60,100,114} It may also be fruitful to conduct research regarding internal threats to OSH translation processes, motivational factors, or systems that inhibit translation activity within work organizations. For example, a new project called “Increasing Adoption of Safety Technologies in Commercial Fishing” will conduct translation research to improve adoption of existing NIOSH engineering interventions to protect deckhands from winch entanglements.⁸⁷

Stage 3 translation research should also: 1) explore means to overcome such barriers and 2) determine effective methods to identify and incentivize, key decision-makers, and intermediaries influencing large scale intervention effectiveness. In essence, stage 3 research should effect widespread change through participant leadership and involvement—discovering who the “right” people are and what they want.^{6,115} Indeed, it is in stage 3 institutionalization research where the most critical knowledge gaps remain, and where the OSH field stands to benefit the most from translation research.

A critical tool that can be used in stages 3 and 4 translation research is the use of systematic reviews. These reviews are means to evaluate how well interventions and plans are being implemented and their impact on various scales.^{32,81,116–119} The use of systematic reviews in occupational safety and health is increasing and it will drive translation research.¹¹⁹

2.4 | Stage 4: Evaluation

Stage 4 seeks to investigate the “real world” health, safety, economic, and well-being impacts of integrating these new OSH discoveries and

interventions into large scale practice. Stage 4 emphasizes research specifically focusing on the impact of translation efforts on workplace illnesses, injuries, and fatalities; thus, this stage should complement surveillance efforts. A good example of stage 4 translation research was described by Lucas et al.⁶⁰ It involved analysis of fatality and survival data for commercial fishing vessels during the period 1991–1997. The study found that “decedents of vessel disasters were less likely than survivors to have received safety training, supporting the hypothesis that training improves survival.”^{19a}

Evaluation stage translation research includes a persistent yet critical need to assess real-world effects of an OSH organization's outputs in short-, medium-, and long-term time frames. This type of work is among the most challenging in OSH research, but OSH organizations can begin to better measure their impact if they can: (1) develop and test methods to assess impact at various time points in the future; (2) utilize ongoing surveillance and retrospective studies to assess impact; (3) utilize systematic reviews and meta-analyses to determine if these are real-world evaluations and what they indicate for worker safety and health^{116,119}; (4) incorporate findings from impact assessments so that new “impact-making” efforts can be developed; and (5) engage their stakeholders in the evaluation process, (eg, monitoring PPE sales, documenting expansion of technology distribution networks or identifying reductions in policy holder workers' compensation claims). Additionally, there is a knowledge gap related to identifying clear causal links between OSH organizations' research translation efforts and related improvements in health and safety outcomes. Thus, evaluation stage translation research efforts should also include specific attention to levels of fidelity and adaptation of interventions as they are adopted into large-scale use.

Important for stage 4 translation research is the need to answer three data availability and use questions: In what way can translation research efforts utilize economic and epidemiological/surveillance outcome data? Are there obvious and fruitful collaborations, especially for stage 4 efforts? Can OSH organizations improve data collection related to translation research in their applied and public health practice efforts. Specifically, can they standardize elements to capture process and outcome data, facilitate economic analysis, validate quality of data, and determine how to gather and use after-action reports, grant reports, and other evidence-based performance measures?

3 | CONCLUSION: USING THE FRAMEWORK

The development of evidence-based guidelines, new findings and interventions, and novel technologies is a continually evolving process. The four stages of translation research (Figure 1 and Table 1) can at times overlap and provide feedback loops to previous stages which can inform improvements in knowledge uptake.

In all instances, translation research should remain focused on solutions, that is, understanding *how best* to reduce the risk of a workplace safety and health problem, *how to change* less effective workplace practices, and *how to overcome* barriers to adoption of new information and integration of new workplace practices. Efforts should

be directed toward those technologies, interventions, and guidance that are scalable, and might be feasibly expected to provide optimal workplace health for many. OSH translation research should emphasize investigating effectiveness (ie, evidence under real-life conditions), and should be broadly thought of as encompassing multifactorial elements that may be drawn from work in biological, engineering, industrial hygiene, psychosocial, economic, legal, cultural, manufacturing, and marketing as well as other possible domains—as all have an impact on workers, employers, and workplaces. Translation research at its best also should study *transferability*—the successful application to diverse workplace settings.¹²⁰ This emphasis on transferability does not ignore factors specific to success in certain workplace settings, but emphasizes a goal of conducting translation research with maximum potential to generalize across workplaces. This also makes particular interventions easier to disseminate, for example, personal flotation device manufacturers are more likely to invest in designing and distributing better products if their consumer population includes more than just commercial fishermen.⁶⁰

Translation research should become an integral part of the complex feedback loop that characterizes the OSH field's value to the nation. As such, translation research should be focused on areas where there is a large burden on workers, employers, and society in terms of morbidity, mortality, cost, and distress or where there is the greatest opportunity for success.^{16,121–125} Translation research findings stand to add significant value by informing and optimizing the work of OSH research, communication efforts, direct product disseminations, and technology transfer. This program of research should increase the likelihood that OSH organizations' effective, science-based OSH information, and technology is sought and used by others who are in a position to make changes in workplaces. This research should also ensure that OSH organizations partner with effective and influential stakeholders and intermediaries in ways that maximize the impact of the organizations' production and dissemination of scientific information and technology. Each translation effort or approach studied should drive new translation research through lessons learned, development of novel methodologies and metrics, and validation of evolving mediums and channels for outreach. Ultimately, translation research needs to focus on whether the outputs of OSH organizations make a difference. Do they have an impact on health, safety, economics, and well-being? For translation research to take hold and grow there will be a need to shift some research investments to the more distal areas of the research-to-practice continuum.

The framework proposed here requires the development of an effort within the OSH field to nurture, promote, and coordinate translation research. This framework was developed because there is a pressing need to focus on the last steps in the process of applying knowledge to protect the health, safety and well-being of workers. Translation research can be helpful in meeting this need.

AUTHORS' CONTRIBUTIONS

Paul Schulte and Carol Stephenson chaired a working group of the authors and developed the first draft. Thomas Cunningham revised the

manuscript. All authors participated in the development of concepts used in the paper and in the editing.

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DISCLOSURE BY AJIM EDITOR OF RECORD

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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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