Grand Challenges for Worker Health, Safety, and Well-Being

The Changing Work Environment

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Introduction

In 2021, the AIHA Board of Directors approved the Grand Challenges for Worker Health, Safety, and Well-Being. According to the White House Office of Science and Technology Policy under the Obama Administration (n.d.), Grand Challenges are "ambitious but achievable goals that harness science, technology, and innovation to solve important national or global problems and that have the potential to capture the public's imagination" (para. 1).

Criteria for the Grand Challenges

The criteria selected by AIHA's Grand Challenges Leadership Team require the goals set by the Changing Work Environment Team to be:

- Big, important, compelling initiatives geared toward solving critical world needs.
- Likely to achieve progress in solving world needs within five to 10 years.
- Capable of generating defined, measurable outcomes.
- Reliant on interdisciplinary collaboration, significant innovations, and long-term sustained commitments to make progress.

The AIHA Grand Challenges covered in this concept paper result from work performed by the Changing Work Environment subcommittee. AIHA, and other organizations, such as the National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Government Industrial Hygienists (ACGIH), have undertaken initiatives to highlight the changes likely to be encountered and the research required to meet those needs. Of particular interest are the *National Occupational Research Agenda for Healthy Work Design and Well-Being* (2020) and the *NIOSH Future of Work Initiative Research Agenda* (2021).

The potential impacts of changes in the work environment on the occupational and environmental health and safety (OEHS) profession are expected to be profound and wide-ranging. This is perhaps best expressed in the foreword of the *NIOSH Future of Work Initiative Research Agenda* (2021):

> Technological innovations, automation, digital transformation, globalization, and—most recently—the COVID-19 pandemic have accelerated the speed at which we live and work. These and other future of work changes continue to impact workplaces and workforces in the U.S. and abroad. The challenge is navigating how best to manage the resulting complex, current, and emerging issues we collectively face.

No one knows for certain what the future holds for occupational safety and health (OSH). What is clear, however, is that it will be influenced by the choices we make today. Proactive steps are needed to ensure that the future of work favorably contributes to the safety, health, and well-being of all workers, their families, employers, communities, and the Nation. (p. iii)

AIHA's Grand Challenges Leadership Team established the Changing Work Environments Team to help define this topic area and offer recommendations for future action. Five topic areas were identified and will be covered in this concept paper, including the following:

1. *Ensure the health, safety, and well-being of workers in nonstandard work arrangements.*
   - Address the needs of gig workers, temporary workers, and those who work outside of traditional workplaces.
2. *Minimize the impacts of shift work, long hours of work, and sleep deficiency on the health, safety, and well-being of workers.*
   - Modify and adapt work schedules to optimize worker safety, health, and well-being.
3. *Advance the health, safety, and well-being of workers affected by rapidly advancing technology.*
   - Incorporate advancements in sensor technology and data storage, as well as interpret the data collected.
   - Address issues associated with the implementation of automation, artificial intelligence, robotics, and other new technologies.
   - Address the impact of the information age on occupational exposure limits.
4. *Improve work design and organizational practices to advance the health, safety, and well-being of workers.*
   - Adopt or modify business organizational practices that improve the workplace and support adjustment to new challenges.
5. *Optimize education, training, and skill-building approaches to improve the health, safety, and well-being of workers.*
   - Meet the needs of existing operations.
   - Develop a skilled workforce to accommodate new technologies
   - Provide training and skill development for workers who may be displaced by new technologies.

Background on each of these topics will be provided to highlight issues observed in the scientific literature. This will be followed by recommendations for what OEHS professionals can do to address these topics more directly as part of the AIHA Grand Challenges Initiative in the next five to 10 years and beyond.

Grand Challenge 1: Ensure the Health, Safety, and Well-Being of Workers in Nonstandard Work Arrangements

Introduction and Background

Increasingly, occupational health scientists and practitioners have focused on understanding nonstandard or alternative work arrangements. Defining which workers fall into alternative work arrangements can be complicated. NIOSH has proposed a taxonomy for defining work arrangements (as cited in Pana-Cryan et al., 2018). The taxonomy clarifies work arrangements according to different matrices, such as whether the work is permanent or temporary, self-employment, job insecurity, compensation, and benefits, among other factors.

There is some evidence that the proportion of the workforce falling into nonstandard work arrangements has been increasing with one study suggesting that there has been a 6% increase in workers employed in such arrangements since 2005 (Katz & Krueger, 2019). However, other research has suggested that the increase is not actually as drastic. The Bureau of Labor Statistics' analysis of data from the May 2017 Current Population Survey (2018) suggested that the percentage of workers employed in nonstandard work arrangements has not increased since 2005. Novello and Stetner (2018) have suggested that BLS' findings from the 2017 survey may have arisen because the survey asked about the respondent's main job. Many workers have multiple jobs, and their other jobs may be more likely to fall into the nonstandard work arrangement category.

Research suggests that nonstandard work arrangements may be associated with different measures of health and well-being. A meta-analysis by Wilkin (2013) found that contingent workers have less job satisfaction than other workers. A literature review (Virtanen et al., 2005) described higher levels of psychological conditions among workers in temporary work.

Remote Work

According to the National Institutes of Health (n.d.), remote work refers to arrangements in which a worker's "official duty station is an approved alternative worksite." Remote work arrangements became more prominent during the COVID-19 pandemic, when many workplaces were able to switch to alternative work arrangements or strove to minimize the amount of time workers spent at centralized work locations to promote physical distancing. Before the COVID-19 pandemic, Barrero et al. (2021) estimated that about 5% of workers were in remote arrangements, a proportion that increased to 20% during the pandemic. Dey et al. (2020) estimated that about 13% of workers worked from home before the COVID-19 pandemic.

It is important to note that the ability to work remotely differs between occupations. Barrero et al. (2021) and Dey et al. (2020) assessed workers' ability to telework across different occupational, demographic, and socioeconomic factors. They found that about 43% of workers were able to telework. The ability to telework was highest among workers with higher educational attainment, older workers, full-time workers, and non-Hispanic white workers.

According to Dey et al. (2020) 1% or fewer of the workers in the following occupation categories were able to telework:

- Farming, fishing, and forestry
- Construction and extraction
- Production
- Transportation and material moving
- Installation, maintenance and repair, and service

The following industries had the lowest percentages of workers able to telework (Dey et al., 2020):

- Agriculture, forestry, fishing, and hunting
- Leisure and hospitality
- Construction
- Transportation and utilities
- Wholesale and retail trade

Some research has explored the health effects of remote work. Based on a review of the literature regarding telework and health, Beckel and Fisher (2022) proposed a model for how telework impacts health, which includes antecedent factors, such as demographics and economics; mediators, such as job characteristics and social context; and moderators, such as gender, extent of telework, and health outcomes. Lunde et al. (2022) suggested that there are not enough studies to make firm conclusions about the impact of telework on health. Some research suggests that remote work may contribute to work stress, especially when infrastructure is not present to support remote work. Additionally, remote work may exacerbate work-family conflicts (Como et al., 2021).

Contingent Work

Polivka and Nardone (1989) have defined contingent work as "any job in which an individual does not have an explicit or implicit contract for long-term employment" (p. 11). Examples of worker categories that fall into nonstandard or alternative work arrangements include independent contractors, on-call workers, workers employed at temporary help agencies, workers provided by contract firms, part-time workers, app-based workers, and freelancers (Katz & Krueger, 2019). According to Howard (2017), a common feature of these arrangements is that workers in them cannot expect their positions to be permanent, even if they perform their jobs well.

App-Based Jobs

App-based jobs are one of the most prominent nonstandard work arrangements, especially in the transportation industry. Apps such as Uber and Lyft have disrupted the transportation industry with negative impacts on traditional transportation, such as the taxi industry. App-based transportation companies have been criticized for treating their workers like independent contractors and not employees. Such arrangements prevent drivers from accessing occupational benefits and employment protections. Other types of app-based jobs are associated with food delivery apps, such as DoorDash, and freelance service apps, such as Fiverr.

Precarious Employment

These changes in work arrangements have often resulted in work becoming more precarious. A systematic review of precarious employment by Kreshpaj et al. (2020) found that the term has been defined in a wide variety of ways. The review identified three specific dimensions that make up the definition of precarious work: employment security (contract relationships and multiple jobs), income adequacy, and lack of rights and protections (unionization, social security, workplace rights, and so on). When conceptualizing precarious employment relationships, research has suggested focusing on three elements: job instability, lack of power and rights, and poor terms of employment. These factors may then have downstream impacts on health, potentially mediated by actual hazards at the workplace, negative effects on material well-being, and the psychological experience of precariousness (Bodin et al., 2020).

Job Insecurity

Shifting employment relationships may impact workers' feelings of security in their employment. There are different definitions of job insecurity. What unites most definitions is that job insecurity refers to the worker's concern about having a job in the future. Various health outcomes may be associated with job insecurity, including drug use (Frone, 2006) and common mental health disorders (Stansfeld & Candy, 2006), like depression (Rugulies et al., 2006; Ferrie et al., 2002) and suicidal ideation (Milner et al., 2018).

Preventive Actions

- Implement or adapt data collection systems to improve the quality of data and action plans to advance health, safety, and well-being. This may include the following:
  - Definitions of routine, non-routine, and nonstandard work, including situations where workers may work alone.
  - Identification of types of standard and nonstandard work tied to safety and health incidents, close calls, adverse outcomes, or worker concerns, including work/life balance issues.
  - Identification of and sharing of outcomes that improve worker safety and health.
  - Auditing data collection systems to ensure they take into account worker demographics, which will help show trends over time.
- Implement or adapt tracking systems to highlight the level of success of interventions to improve worker health and safety and any follow-up actions needed.
- Develop and implement continual improvement systems for the identification and resolution of occupational diseases and injuries whenever possible.

Potential Outcomes

- Conduct benchmarking to review systems and optimize the measurement and improvement of workplace conditions.

Metrics and Assessing/Measuring Progress

- Develop metrics to assess and measure progress. This may include reactive measures, such as reduced incidence rates, and proactive measures, such as survey results indicating improved worker satisfaction, increased productivity, and fewer reports of issues.
- Develop targets to drive innovation over the next decade and beyond, with the goal of reducing or eliminating preventable occupational diseases and injuries whenever possible.

Interdisciplinary and Cross-Sector Involvement

- Work with management, staff, and workers to identify, evaluate, and resolve workplace issues. This may include working with medical, mental health, and human resources
- Incorporate concepts from government agencies, professional associations, and research to address Total Worker Health® (TWH) issues.

Calls for Innovation

- See content above.
- Develop clear and consistent definitions for standard and nonstandard work activities that can be utilized to improve workplace conditions.

Next Steps: Progress and Future Directions in Research, Education, Practice, and Policy (AIHA & ACGIH, 2025)

- Promote data collection by occupational health surveillance systems on work arrangements, including information on workers with multiple jobs and associated adverse health outcomes.
- Measure the prevalence and characteristics of nonstandard work activities and identify workers and workplaces with nonstandard work arrangements.
- Identify, evaluate, and share:

- Characteristics of nonstandard work that are detrimental to worker health in different economic sectors and for various demographic groups.
- Socioeconomic and other risk factors, such as job insecurity, that affect the prevalence of precarious work and jobs with nonstandard work arrangements.
- Interventions that improve the safety, health, and well-being of workers in nonstandard work arrangements.

- Promote research to evaluate the safety, health, and well-being of workers in nonstandard work arrangements. This should include:
  - Community-based participatory research and policies that prevent workplace discrimination.
  - Worker involvement in identifying and addressing hazards without fear of retaliation.
  - Education and training efforts that reflect the specific needs of these workers.

Role of OEHS Professionals

- Network with other OEHS professionals, workers, and management to develop effective exposure assessment systems and strategies to evaluate and manage standard and nonstandard work activities.
  - The *Defining the Science Research Agenda* from AIHA and ACGIH (2025) may provide useful guidance in achieving this goal.
  - See also the AIHA Grand Challenges concept paper on improving exposure assessment.
- Conduct benchmarking, information sharing, and other promotional activities to highlight successes and challenges in evaluating and managing standard and nonstandard work activities.

Grand Challenge 2: Minimize the Impacts of Shift Work, Long Hours of Work, and Sleep Deficiency on the Health, Safety, and Well-Being of Workers

Introduction and Background

Shift work refers to work during hours outside of a normal day shift. There are different categories of shift work, including regular evening and night shifts; rotating shifts, in which a person works shifts on alternating days, nights, or evenings; and split shifts, in which a person works multiple shifts during the same day. Additionally, the definition of shift work includes both on-call work as well as irregular schedules (Williams, 2008).

Increasingly, research has documented the health impacts of shift work. Many of the health impacts of shift work likely operate through disruptions to workers' circadian rhythms. This disruption of circadian rhythm may have downstream consequences on different systems in the body, including hormones, metabolism, and cell regulation (James et al., 2017). Shift work may also have impacts on health behaviors, such as increasing likelihood of smoking, decreased physical activity, and poor diet (Nabe-Nielsen et al., 2011; Nea et al., 2015). A variety of negative health outcomes have been observed among workers employed in shift work, including poor mental health (Zhao et al., 2019), adverse pregnancy outcomes (Cai et al., 2019), strokes (Rivera et al., 2020), Type 2 diabetes (Gan et al., 2015), and higher rates of alcohol consumption (Richter et al., 2021). Beyond the health and safety of the workers themselves, shift work may also be a threat to others. Examples include risks to patient safety in healthcare settings (Costa et al., 2021) and the greater incidence of car crashes when drivers are fatigued (Barger et al., 2005).

Workers in different occupations and industries have been identified as having different types of shift work arrangements. The Bureau of Labor Statistics (2019) found that over 80% of employees reported working regular day shifts. This included services, transportation and material moving, sales, and office and administrative support occupations had a higher percentage of workers in regular daytime shifts. In contrast, 16.4% of workers were employed in non-regular daytime shifts, including evening, night, rotating, irregular, and split shifts. The leisure and hospitality, wholesale and retail trade, and transportation and utilities industries had higher percentages of workers in these non-regular daytime shifts. BLS' analysis also found that Black and Hispanic workers, as well as workers with less than a high school diploma, were more likely to be employed in non-regular daytime shifts than other workers. Other studies have confirmed these associations between demographic factors and shift work (Alterman et al., 2013; Hawkins & Hernandez, 2022).

Different interventions have been suggested as ways to protect workers who are exposed to shift work as part of their job. Some of these interventions focus more on individual aspects of the effect of shift work on health, such as assessments of workers' fitness to engage in shift work and educating workers about the impact of shift work on health. Other interventions focus on organizing shift schedules in ways that lessen the detrimental impact of shift work, such as by limiting night work and reducing consecutive night shifts (Costa, 2010). In 1990, the International Labour Organization passed a convention regarding night work. The convention describes the right to health assessments before engaging in night work and the right to transfer to shifts at other times for those not fit for night work, among other elements. Patterson et al. (2023) suggested that allowing naps at work for night shift workers may have beneficial impacts.

Preventive Actions

- Conduct benchmarking of effective practices to minimize adverse outcomes, including:
  - Shift scheduling, especially evening shifts, night shifts, and alternating between shifts.
  - Extended work shifts, overtime, and double shifts.
  - Adverse health effects, including fatigue, sleep deprivation, and work-life balance issues.
- Implement practices or adapt work scheduling to optimize shift work and minimize adverse outcomes, including:
  - Adjust shift scheduling to best fit worker needs.
  - Minimize extended work shifts or providing sufficient rest.
  - Optimize schedules to minimize fatigue, sleep deprivation, and work-life balance issues.
- Consider the use of employer-provided transportation to or from work, especially in international arrangements.

Potential Outcomes

- Develop metrics to assess and measure progress.
- Develop targets to strive for in the next decade and beyond.

Metrics and Assessing/Measuring Progress

- Develop, evaluate, and implement surveillance methods that measure the prevalence and characteristics of shift work, long work hours, and other factors that may lead to fatigue and adverse health outcomes in the workforce and identify workers affected.

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Interdisciplinary and Cross-Sector Involvement

- Work with management, staff, and workers to identify, evaluate, and resolve any actual or potential workplace issues.
- Work with medical, mental health, and human resources personnel to identify issues, manage their outcomes, and implement strategies to minimize future adverse impacts.
- Incorporate concepts from regulatory agencies, professional associations, and research findings to address TWH issues.

The Need for Innovation

- See the interdisciplinary and cross-sector involvement section above.

Next Steps: Progress and Future Directions in Research, Education, Practice, and Policy (AIHA & ACGIH, 2025)

- Identify, test, and share:
  - Interventions that reduce the adverse safety and health consequences of shift work, long work hours, and other factors that lead to fatigue in the workplace.
  - Interventions for workers in shift work and long work hours, especially in occupations involving public safety, such as health care, law enforcement, transportation, and utilities, in which the consequences of errors due to fatigue can be especially severe to members of the public.
  - Strategies for implementing and disseminating effective interventions that reduce the adverse health and safety consequences of shift work, long work hours, and other factors that lead to fatigue in the workplace.

Role of OEHS Professionals

- Network with other OEHS professionals, workers, and management to develop effective exposure assessment systems to evaluate and manage shift work activities and health outcomes.
  - The *Defining the Science Research Agenda* from AIHA and ACGIH (2025) may provide useful guidance in achieving this goal.
- Conduct information sharing and other promotional activities to highlight successes and challenges in evaluating and managing shift work activities.

Grand Challenge 3: Advance Health, Safety and Well-Being of Workers Affected by Rapidly Advancing Technology

Introduction and Background

Organizations are increasingly utilizing advancements in technology to improve their current operations and meet new market needs with the development of innovative products and services. OEHS professionals will need to adapt their approaches to exposure assessment and control to accommodate these new technologies. While this concept paper does not provide an exhaustive review of these new technologies, it does cover several important trends and advancements.

Changes in Manufacturing Processes, Chemicals, and Exposures

Traditional manufacturing and material processing are undergoing significant advancements that are changing the types of worker exposures that OEHS professionals will encounter. Examples include the following:

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- *Additive manufacturing or 3D printing*: The field of 3D printing has undergone expansion from the making of parts from thermoplastic resins to powder bed fusion and carbon digital light synthesis. The scale of the operations has also expanded to include:
  - Building construction using a variety of materials, from concrete to an epoxy or other resin structure.
  - Biomedical applications, such as tissue engineering and repair, drug delivery, and the creation of custom implants.
  - The deposition of vaporized material.
  - The use of a variety of energy sources, including ultraviolet light, lasers, or electron beams.
- *Nano- and carbon fiber materials*: The behavior of nanomaterials may be different than traditional materials in terms of routes of exposure and behavior in the body. As a result, traditional engineering controls and personal protective equipment (PPE) may not be as effective at minimizing exposures to nanomaterials as with traditional materials. The OEHS professional should scrutinize the use of nanomaterials and evaluate controls to minimize worker exposures.
- *Chemical innovations*: Organizations may be using new chemistries and chemicals in their products or in the processes used to make them. This is expected to create new challenges in conducting risk assessments due to the lack of information on health effects and adequate methods for assessing worker exposures. This is expected to create unique challenges in the evaluation and control of potential hazards. OEHS professionals will need to develop and use new and innovative techniques and technologies to properly assess risks and the success of controls.

Refer to the AIHA Grand Challenges concept paper on improving exposure assessments for additional information.

Advancements in Sensor Technology and Big Data

In recent years, there has been significant improvement of existing sensors and development of new types and varieties of sensors to conduct workplace exposure assessments. Sensors continue to become smaller and provide greater capabilities at lower costs. This has produced a wide variety of new and updated "wearable" technologies that may include telemetry, allowing real-time monitoring of worker exposures and even health conditions. It has also contributed to the expansion of fixed sensor systems to provide monitoring of workplace conditions and alerts in the event of a process excursion.

However, the increasing use of sensor technology is likely to result in a tremendous increase in the amount of data generated and the need for storage. This raises several challenges for the OEHS professional:

- Most meters accumulate data either by the minute or second. Some newer personal gas meters may have multiple sensors, each generating data. Depending on the number of workers using the meters at a site, the data generation and storage needs may be significant. Fixed gas detection systems would add to this volume of data.
- There is a danger that capabilities to store and analyze data may be outpaced by the volume of data. While data storage costs have come down in recent years, they could still be a significant factor.
- The increase in data volume may also result in unexpected consequences in terms of analysis. Software to analyze the data is likely to have limitations as to how much data it can handle at one time at a reasonable cost.
- Smart video using artificial intelligence (AI) is another source of significant volumes of data, which will increase as the technology is adopted at more work sites. This also has implications for data analysis and the privacy of people being recorded in the videos.

- More time will be required to manage and interpret the data. New software tools will help, but a qualified professional still needs to be involved. If data is not reviewed, risks may be missed, resulting in incidents that could have been avoided, as well as accompanying liabilities.

- Rapid changes in hardware and software may raise issues, as they need to be updated. This is time consuming, and data compatibility may become an issue with newer versions. For example, a software platform that became obsolete five years ago may yield data that is no longer accessible in a usable format, unless the data can be converted into a general format or mapped to the new system.

Refer to the AIHA Grand Challenges concept paper on improving exposure assessments for a more in-depth discussion of these and other issues.

Impact of the Information Age on Occupational Exposure Limits

The impact of the "Information Age" on OEHS cannot be overstated. Like many fields, technology and the internet have greatly expanded the type, breadth, and manner in which OEHS professionals use information. This has had real benefits to OEHS in terms of increased awareness of potential health impacts from the environment, whether at work or away from work. This has led to questions about what workers may be exposed to and whether they are being appropriately protected.

One of the impacts felt by OEHS professionals is that it is increasingly challenging to keep up with the types and volume of information available. OEHS professionals are spending increasing amounts of time answering questions that workers may bring up, staying abreast of the latest research, and staying current with information available from regulatory bodies and professional associations, such as AIHA, ACGIH, and others.

Another area where the Information Age is having an impact is in terms of occupational exposure limits (OELs) for both chemical and physical agents. It is well known that the OSHA permissible exposure limits (PELs) and ACGIH threshold limit values (TLVs) have limitations in terms of being up to date and in the number of chemical and physical agents they cover. Many large, global organizations utilize practices developed in other countries that provide additional worker health protections. For example, it is well known that gaps in OEL information in the U.S. may be supplemented with OELs from Germany, Britain, France, South Korea, and Taiwan. Any additional gaps may be filled with OELs that the organization has established to provide guidance at its own locations. The OEHS professional will need to understand the differences between these OELs, help develop appropriate worker protection policies, and conduct training and answer questions on these topics.

Exoskeletons and Robotics

The availability of exoskeleton systems and robotic assistants is rapidly expanding and will receive greater use in the workplace. This is expected to have wide-ranging impacts on operations, including the following:

- *Exoskeletons*: One of the advantages promoted for the use of exoskeletons is that the worker is expected to experience far less stress on the body from heavy lifting, as well as repetitious lifting or other activities. However, these systems are new enough that the effects of using them repetitively are not yet fully understood. A few examples include the following:
  - The fit of an exoskeleton system will be critical to help optimize its performance. A poor fit could result in increased risk of muscle and joint strains.

– Any increases in the weights lifted and repetitions performed may result in stress levels that result in injury. In addition, failure of an exoskeleton system may cause new problems from system breakdowns or malfunctions and software glitches. For example, this could result in an exoskeleton joint failure that creates an unbalanced system during a heavy lift or other activity, causing undue strain on the user.

- *Robotics*: While robots have been in use for many years, their use is changing with the availability of many more applications and greater use of the worker-robot interface. This includes the traditional robots used in manufacturing facilities, often protected by fencing, and the robots now moving around plant floors, interacting with workers. New types of risks will need to be identified, evaluated, and controlled. OEHS professionals should play an important part in the design and use of these new robots.

Artificial Intelligence

AI is being touted as having great potential to improve efficiency and safety in the workplace. Examples include the following:

- *Machine learning*: According to NIOSH (2021), some AI systems have "the capability of analyzing large amounts of data in a fraction of the time it would take a human, allowing a wide variety of tasks to be automated" (p. 14). Benefits to worker safety, health, and well-being may include removing humans from repetitive, dangerous, or hazardous tasks and locations. However, these systems are still untested, and an in-depth risk-benefit analysis should be conducted to identify and mitigate any risks and potential to displace workers.

- *Document creation*: AI can generate documents from a wide variety of sources in a very short period of time. This offers the capability for the OEHS professional to generate information on workplace-related issues and risks, potentially saving them a substantial amount of time researching topics of interest. Some or all of the information generated by AI may be incorrect or misleading, requiring the user to vet the document that is provided.

- *Smart video integration*: An exciting and developing field in AI is the use of so-called "smart video" systems. These systems view work areas via cameras, use AI to identify risks in real time, and quickly notify people of risks based on their seriousness. Examples of risks that may be identified using smart video include near misses with lift trucks, improper use of PPE, poor ergonomic practices, and even excessive vapor releases. This has the potential to increase worker protection by identifying many risks that would otherwise not be caught in audits involving spot identification of issues. The system can automatically generate reports and videos of, for example, the number of near misses. Nonetheless, the use of video with integrated AI comes with both benefits and issues of concern, such as the following:

  – Benefits:
    » Real-time evaluation of workplace risks, allowing for feedback to workers and improvement of workplace conditions.
    » Verification of the proper use of PPE to identify potential gaps in awareness and training.
    » Identification of hazardous conditions, such as near misses by lift trucks, vapor or chemical releases, or workers experiencing medical emergencies.

  – Issues of concern:
    » Misuse of the system to monitor productivity, potentially resulting in negative impacts on workers. Such monitoring systems could be perceived negatively by workers as focused too much on production and not on risk reduction.
    » Misuse of a system to identify workplace rule infractions. This could create a perception of a punitive "Big Brother" situation.

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– Privacy concerns and potential misuse of monitoring data may become an issue if rules for smart video use are not defined carefully and applied consistently. These rules should be established after careful consideration of how data generated by the smart video system is expected to be obtained, used, and stored.

Personal Protective Equipment

Technology has been expanding in the area of PPE and methods to assess its effectiveness. Examples include the following:

- Fit testing for hearing protection is becoming more common and may soon be as routine as fit testing for respirators. This is likely to increase the workload of OEHS professionals to meet these demands or help implement noise reduction programs when hearing protection is no longer needed.

- The certification requirements for PPE are increasing in the U.S. and other countries. This may result in some conflicts due to differences in the approval processes and the criteria used. Some effort will be needed to determine which certifications are best, especially in organizations that have global operations. Alternatively, it may be possible to substitute another form of PPE that resolves any possible disputes. For example, a powered air purifying respirator (PAPR) may be substituted for negative pressure respirators.

- Obtaining a proper fit of PPE for all workers is becoming a greater challenge in a global workforce due to wider differences in anthropometry of the across worker populations. This may require a broader range of types and sizes of PPE to accommodate the workforce. OEHS professionals will need to determine which PPE suppliers provide better body analysis data to meet these requirements.

Remote Work

New technologies are increasing the amount and type of work that can be done remotely. Common examples include office work, telemedicine, and monitoring of remote workstations. While many workers may be removed from risks in the workplace, other issues may arise if the process is not carefully managed. Examples include the following:

- Groups working remotely may become disconnected from the work environment. Isolation may result in a disconnect from the work area, especially if workers spend limited time on site.

- Reduced team interaction and learning may occur and need to be addressed. For example, an engineer or software specialist working remotely to set up equipment or resolve operational issues may not get the same input from workers as a person at the site.

- If a problem arises, there may not be anyone on site to take corrective action in a timely manner. In some situations, like a chemical spill or environmental release, this could result in workers, contractors, and community members being at increased risk of harm.

- Ergonomics can be an issue in remote work settings, requiring assessments and interventions.

Additional information on remote work is provided in the section on the safety, health, and well-being of workers in nonstandard work arrangements in this concept paper.

OEHS Training

Historically, training sessions typically consisted of lectures in large group settings. Information was presented in the hope workers would absorb the important portions of it. Since then, training has evolved to include more interactive sessions, with worker discussions and some level of knowledge verification. With newer technologies, there is a broader range of training methods to better adapt to worker needs:

- *Virtual reality*: The use of virtual reality in training started with demo programs over 20 years ago but did not make it into broad use. Newer and easier-to-use platforms are making virtual reality an option for training, including 3D workplace walkthroughs and demonstrations that enhance the learning experience. This can even be extended into the work environment with projection screen eyewear used by some teams to project maintenance diagrams.
- *Language translation*: With an increasingly global workforce, workers speak a greater diversity of languages. OEHS professionals are expected to meet greater demands for training in those languages and to respect cultural differences that could impact health and safety. Fortunately, technology is quickly improving, including tools to help with nearly real-time language translation and easier identification of cultural differences.
- There is an opportunity to learn from university education, such as asynchronous classes.

Refer to the section in this document on education, training, and skill-building approaches for additional information on this topic.

Preventive Actions

- Evaluate, test, and implement effective workplace assessments and controls systems to minimize adverse outcomes from the implementation of new technologies.
- Conduct benchmarking of effective practices to minimize adverse outcomes resulting from new technologies and potential job displacement.
- Explore remedial and resiliency-building interventions that can better prepare or safeguard workers from potential job displacement or loss due to automation.
- Participate in the design or purchase of new equipment and technologies to anticipate safety and health issues whenever possible.

Potential Outcomes

- Improved ability to evaluate the impact of new technologies through the following activities:
  - Design of new processes and purchase of new equipment.
  - Exposure assessment strategies and tools to evaluate the impact of new technologies, including robotics, exoskeletons, AI, and smart video systems.
- Improved ability to store, archive, and analyze large amounts of exposure assessment data and maintain appropriate data security and privacy controls.
- Greater ability to find and use OELs based on sound science from a variety of national and international sources and organizations.
- Improved ability to use appropriate and effective PPE that meets current and anticipated regulatory requirements for a diverse workforce.
- Increased ability to use new technologies to conduct effective training for a diverse workforce.

Metrics and Assessing/Measuring Progress

- Develop, evaluate, and implement methods that measure the characteristics of new technologies and adapt them to prevent adverse health outcomes in the workforce.
  - Track the magnitude and distribution of technological job displacement of workers by occupation, sociodemographic characteristics, and work arrangements.

Interdisciplinary and Cross-Sector Involvement

- Work with management, staff, and workers to identify, evaluate, and resolve any actual or potential workplace issues from new technologies, including job displacement.
- Work with medical, mental health, and human resources personnel to identify issues, manage their outcomes, and implement strategies to minimize future adverse impacts.
- Incorporate concepts from regulatory agencies, professional associations, and research findings to address TWH issues.

Calls for Innovation

- Active promotion of continual improvement processes by professional organizations, regulatory agencies, and trade associations to address the challenges of new technologies head on.
  - Share stories of successful implementations that can provide valuable guidance to other organizations to improve their health and safety performance and meet organizational goals and objectives.
- Develop effective, evidence-based design, implementation, and dissemination strategies for best practices in assessment, intervention, and program evaluation, which is critical to the translation of research into practice.
  - Emphasize evidence-based methods that are cost effective and realistic for small- and medium-size organizations without dedicated staff or access to internal experts.

Next Steps: Progress and Future Directions in Research, Education, Practice, and Policy

- Identify, test, and share implementation and dissemination strategies for effective interventions that reduce the adverse health and safety consequences and number of workers affected by job displacement from the use of new technologies in the workplace.
- Develop and disseminate new OEHS policies and practices to assist policy makers and employers aiming to prevent or mitigate the adverse consequences of occupational polarization, that is, when technology is more likely to replace tasks performed in middle-skill work than lower-skill and higher-skill work (NIOSH, 2021).
- Promote research and translation activities on the impacts of automation, technological job displacement, and occupational polarization on worker health, safety, and well-being across occupations and industries (NIOSH, 2021).

Role of OEHS Professionals

- Network with other OEHS professionals, workers, and management to develop effective exposure assessment systems to evaluate and manage work activities and health outcomes.
  - The *Defining the Science Research Agenda* from AIHA and ACGIH (2025) may provide useful guidance in achieving this goal.
- Conduct information sharing and other promotional activities to highlight successes and challenges in evaluating new technologies.

Grand Challenge 4: Improve Work Design and Organizational Practices to Advance the Health, Safety, and Well-Being of Workers

Introduction and Background

OEHS initiatives in an organization may often be characterized on a sliding scale of responsiveness. This scale ranges from purely reactive on one end of the spectrum to essentially proactive on the other end. Initiatives that are more reactive tend to focus on identifying risks from current or past incidents and lack systems to elicit worker feedback on workplace risks before incidents take place. As a result, little is done to conduct an organized process to proactively recognize, evaluate, and control workplace issues.

In contrast, organizations that are more proactive tend to have a much more organized approach to risk assessment and management. More emphasis is placed on feedback mechanisms so that workers can provide information on workplace risks before incidents take place. Additionally, such proactive approaches are more likely to include mechanisms focused on anticipating issues related to new processes or equipment brought into the workplace. In this way, risk assessments can be conducted early in the design or purchase phase of a project when the complexity and cost of changes tend to be lowest.

The more proactive approach to risk assessment and management may offer distinct advantages as organizations approach the future expecting significant changes in the pace and impact of technological advancements. Examples include the following:

- Greater use of automation
- Increasing use of autonomous and interactive robotics
- More widespread applications of AI

An organization that focuses more on anticipation and early intervention is expected to be better able to adapt to these changes, minimize any adverse impacts on its workforce, and maximize its competitiveness. Examples may include reduced workplace incidents, better training of workers to perform operations safely, and utilization of workers in other operations who otherwise might be displaced from their job.

Some OEHS professionals may find their efforts are largely devoted to reacting to workplace issues as they arise and that they lack an organized process to proactively recognize, evaluate, and control workplace issues. This makes it difficult to deal with existing issues, let alone anticipate issues related to new processes or equipment brought into the workplace. As the pace of technological change increases, it becomes even more difficult to anticipate potential risks in the workplace and workforce in a timely manner.

Preventive Actions

One of the most effective ways to implement a more proactive approach to risk assessment and management is with the development of better organizational practices. OEHS management system standards have been developed over the years and shown to have positive results for the organizations that have implemented them. This includes voluntary standards created in the U.S. and other countries. Examples include:

- ANSI/ASSP Z10, *Occupational health and safety management systems*
- The ISO 14000 family of environmental management standards
- The ISO 45000 family of occupational health and safety standards

A key element of these management systems is the use of a continual improvement cycle, often referred to as a plan-do-check-act cycle. Key aspects of these management systems include:

- They are performance-based, as well as adaptable and scalable to fit the needs of different sizes and types of organizations.
- They require the involvement of all levels of the organization, with specific roles for workers, technical staff, managers, and leadership.
- They include systems for feedback and early reporting by workers and others at the organization. These may include reactive metrics that document incidents, as well as more proactive feedback reported before incidents take place, such as close calls, safety observations, or worker concerns. They may also include safety or ergonomics teams with training to help identify and resolve workplace issues.
- They incorporate the involvement of workers, technical staff, and managers in the design phase of projects and the purchase of new equipment to better accommodate the needs of the organization and the workforce.
- They may be adjusted to fit workforce needs, including but not limited to the following:
  - Workforce demographics, chronic health conditions, and psychosocial conditions.
  - Bias and discrimination.
  - Impacts from advancing technologies, including automation, AI, and robotics.
  - Advancements in the science and technology of OEHS, including sensors, sampling equipment, analytic methods, and control technologies.

The Occupational Safety and Health Administration (OSHA) has adopted a similar approach to health and safety program management systems by focusing on their effective implementation. The agency's efforts have centered on two primary areas. The first involved the creation of several guidance documents based on the *Safety and Health Program Management Guidelines* (1989). These documents include several industry-specific guidelines to help organizations customize their approaches to improving health and safety performance. The guidelines were also used to promulgate the agency's standard, Process Safety Management of Highly Hazardous Chemicals (1992). A revised version of the guidelines was published in 2016.

OSHA's second area of emphasis involved its Voluntary Protection Programs (VPP). These programs were created to promote collaboration between organizations and OSHA and recognize organizations for achieving significant success in improving safety and health performance.

Potential Outcomes and Needs for Innovation

The goal is to establish a continual improvement process with robust worker feedback mechanisms to eliminate occupational injuries and illnesses in a period of 10 to 15 years. To evaluate progress toward this goal, it is necessary to review system performance on a recurring basis. This may include internal reviews, as well as benchmarking with other organizations and sharing best practices. This may include, but is not limited to, the following:

- Written policies and procedures on such topics as:
  - Disability and return-to-work accommodations.
  - Discrimination based on age, gender identity, ethnicity, and culture.
  - Chronic health conditions that may or may not be work-related, including both physical and mental health conditions.

- Health and safety reviews in the development and rollout of new processes and in the purchase of new equipment.
- State and federal agency data delineating incident trends, including but not limited to:
  - Age and gender.
  - Chronic health conditions.
  - Ethnicity and cultural differences.
- Collection and sharing of best practices for:
  - Early reporting of incidents and concerns by workers.
  - Overcoming barriers to reporting, including cultural differences, language, and discrimination.
- Adaptation to changes in demographics and work status.

Steps Toward Continual Improvement

- Active promotion of continual improvement processes by professional organizations, regulatory agencies, and trade associations to meet health and safety challenges head on.
- Share stories of successful implementations that can provide valuable guidance to other organizations to improve their health and safety performance and meet organizational goals and objectives.
- Develop effective, evidence-based design, implementation, and dissemination strategies for best practice assessment, intervention, and program evaluation, which is critical to the translation of research to practice.
- Emphasize evidence-based methods that are cost effective and realistic for small- and medium-size organizations without dedicated staff or access to internal experts.

Role of OEHS Professionals

- Be active in the development and implementation of a continual improvement process to improve health and safety management performance.
- Interface with both management and workers to facilitate discussion around health and safety issues and the development and implementation of workplace improvements.
  - This includes the implementation of procedures to highlight issues as proactively as possible to minimize exposure risk and reduce the costs of making improvements.
  - The goal is to implement changes that benefit both workers and business objectives.
- Evaluate work design and practices, exposure assessment, and benchmarking of best practices in other organizations

Metrics and Assessing/Measuring Progress

- Audit, measure internal progress, and benchmark best practices in other organizations.

Future Directions in Research, Education, Practice, and Policy (NIOSH, 2020)

Identify, test, and share:

- Effective strategies for comprehensive, systems-based interventions (that is, sets of organizational and work practices and how they relate to and interact with each other in real-world settings) and evaluation of those interventions.

- Interventions to increase the impact of management systems, quality improvement methods, leadership styles, and supervisor and coworker support approaches on worker and organizational outcomes.
- Best practice methods for assessing worker well-being in individual workplaces and identifying deficits that need to be addressed.
  - Focus special attention on understanding how these best practice methods may vary by worker or organizational characteristics, such as age, gender, ethnicity, occupational group, and industry sector.
- Relationships between labor and management and their involvement in establishing overall work policies and practices and the related implications for worker health, safety, and well-being.
- Data on differences in worker and organizational needs, preferences, practices, and outcomes by industry, region, size, structure, and type of job.
- Characteristics of the built environment, such as ergonomics and workspace design, that in combination with psychosocial work environment characteristics, promote worker health, safety, and well-being.
- Organizational and managerial strategies to respond to misuse of opioids and illicit drugs by workers. These strategies could include:
  - Identifying and correcting demanding work organizational factors that increase the risk of substance misuse by workers.
  - Identifying ways to assist workers with substance use disorders while protecting their privacy.
  - Identifying ways to support workers with substance use disorders through return-to-work assistance and continued employment, while protecting worker and public safety.
  - Facilitating effective treatment through anti-stigma interventions and improved access to health care.

Grand Challenge 5: Optimize Education, Training, and Skill-Building Approaches to Improve the Health, Safety, and Well-Being of Workers

It should be noted that this section provides a discussion of the training of workers and OEHS professionals to improve the health, safety, and well-being of workers. It does not directly address how academic programs and training organizations, such as AIHA, will need to adapt. These topics will be addressed in another forum.

Introduction and Background

OEHS professionals have been key players in organizations by providing education and training to minimize workplace hazards and risks. However, changes in worker demographics, technologies, and work schedules pose unique challenges to OEHS professionals' abilities to provide effective education and training. Some of the challenges include the following:

- Making safety and health training accessible and effective for workers who may not speak English, may speak English as a second language, may be illiterate, or may be new hires, temporary workers, or gig workers (NIOSH, 2020).
- Overcoming communication barriers, including those that arise respecting workers who may not understand or have difficulty accessing electronic training, and from training content that may not resonate or be understandable to learners in terms of local cultures and contexts (Flynn et al, 2018).
- Ensuring that training keeps up with new and rapidly advancing technologies prior to implementation. OEHS professionals may find themselves having to learn and understand the technology to adequately train workers on hazards and risks.

The potential results of these problems are that workers may not have adequate training to understand the hazards and risks or preventive measures that can be taken to reduce the risk of injury or illness on the job. This may cause workers to be afraid to speak up or become angry and frustrated with their employers, which may result in mental or physical issues and reduced productivity, as well as affect coworkers by increasing their emotional and physical risk (NIOSH, 2020; O'Connor et al., 2014).

OEHS professionals who are not able to provide effective training and content can lose respect and credibility with colleagues and workers.

To help address these issues, the following sections will focus specifically on ways to improve the effectiveness of worker training by OEHS professionals, given the increasing diversity of the workforce and the impact of new and rapidly changing technologies.

Preventive Actions

There are many opportunities for improvement in the training programs provided to workers, as well as the training that OEHS professionals receive. They include the following:

- *Languages*: Worker training must:
    - Accommodate different languages and cultures.
    - Eliminate cultural and coworker bias whenever possible.
    - Recognize the importance of local context to developing and implementing successful safety measures (Flynn et al., 2018).
        » Seek input on how best to adapt programs and initiatives to meet those needs.
    - Overcome the high levels of job insecurity that temporary and contractual workers may face, as well as their feelings that they have little influence on decision-making that affects their work conditions. Workers in this situation may include:
        » Undocumented workers who may be fearful that speaking up for their rights to safety and health may result in deportation.
        » Recent immigrants who may be reluctant to cause conflicts with their employers.
    - Training programs directed towards these more vulnerable groups must recognize the many barriers that trainees face in putting lessons learned from training programs into action (O'Connor et al., 2014).
- *Existing operations*: Provide training on existing operations to improve safety and health while optimizing performance.
    - O'Connor et al. (2014) noted that simulations, hands-on exercises, and other engaging training methods are more effective in helping workers acquire knowledge and reduce negative outcome when compared to less engaging training methods, such as lectures. This study also recommended that organizations involve their target audience of workers from the beginning and tailor training to their reality.
- *Design and purchase of new equipment*: Work with management, engineers, and other staff members to involve workers in the review and purchase of new equipment, including by:
    - Evaluating new equipment and work processes for safety and health, as well as production goals.
    - Developing training for new equipment operation and new process deployment to maximize safety and health.

- *Impact of new technologies*: Provide training and skill development for workers who may be displaced because of new technologies so that they can work elsewhere in their organization or find outside employment. According to NIOSH's *Future of Work Initiative Research Agenda* (2021), "most evidence points to an array of skills that many workers will need to have in all job categories as the future unfolds," although opinions differ as to exactly what skills will be required (p. 24). Acquiring these abilities and other elements of human capital—that is, skills, knowledge, and experience assessed with respect to their value or cost to an organization—will help workers "transition more quickly and meet volatile labor markets, automation, and employer demands" (p. 25). The array of skills identified by NIOSH as critical to future workers (2021, pp. 24-25) includes the following:

  - Sense-making: the ability to assess underlying meanings or significance of items being articulated.

  - Social intelligence: the ability to connect with others in a profound and direct manner.

  - Novel and adaptive thinking: the ability to imagine solutions beyond the status quo.

  - Cross-cultural competency: the ability to operate effectively in diverse cultural settings.

  - Computational thinking: the ability to translate data into abstract ideas and comprehend data-based reasoning.

  - New media literacy: the ability to determine, develop, and communicate content using new media forms.

  - Trans-disciplinarity: the ability to translate concepts across multiple disciplines.

  - Design capability: the ability to represent and develop tasks and work processes for intended outcomes.

  - Cognitive load management: the ability to differentiate information by importance and use various tools and techniques to maximize cognitive function.

  - Virtual collaboration: the ability to work productively in virtual group settings.

- *Development of new training technologies and methods*: Evaluate the effectiveness of training technologies and methods to achieve the maximum impact. O'Connor et al. (2014) have described the following four approaches to delivering OEHS training:

  - Public health campaigns or social marketing programs: creative efforts to reach workers with OEHS messages through the community. A variety of media have become increasingly important to this approach.

  - Train-the-trainer programs: these programs to have positive impacts such as giving participants the confidence and willingness to make workplace health and safety improvements, enabling further use of training materials as resources, and increasing communication between workers and managers. However, in a high-quality train-the-trainer program, trainees must receive intensive follow-up, coaching, and resources.

  - Lay health advisor programs: This approach has been highly successful in public health practice and has established a strong track record, particularly among Latino immigrant communities. Lay health advisors have also been successful in OEHS programs for construction workers, farmworkers, immigrant day laborers, and poultry processing workers.

  - Direct worker training: Most OEHS training and education programs involve training workers directly in places such as workplaces, union halls, or communities. "Such training may range from brief interactions with workers on the street to highly structured, long-term training programs" (O'Connor et al. 2014, p. 4).

Potential Outcomes

The potential outcomes from these improvements to training and skills development are different for workers and OEHS professionals. For workers, the goal is to achieve risk reduction and prevent illness and injury on the job through better understanding of hazards, risks, and control measures. According to NIOSH (2020), "the opportunity to gain new skills and experiences can increase worker motivation and job satisfaction and help workers more effectively manage job stress" (p. 17).

Meanwhile, OEHS professionals who are able to work with people and companies from diverse cultural backgrounds, including those outside of industrialized Western nations, can better meet the safety needs of foreign investors and workers (Flynn et al., 2018).

Metrics and Assessing/Measuring Progress

- Develop systems to test, implement, and modify training programs to optimize effectiveness.
  - These systems may benefit from benchmarking within the organization or with other organizations that have successfully implemented effective training programs.
- Develop metrics to evaluate the effectiveness of training programs and develop targets for progress that can be made in the next decade and beyond.

Interdisciplinary and Cross-Sector Involvement

- Develop partnerships with other OEHS professionals inside and outside of the organization to optimize the content and delivery of training.
- Consider developing partnerships with occupational health and safety organizations, such as NIOSH, to develop training methods and content for both OEHS professionals and workers.
- Advocate for the inclusion of information on safety and health risks and control measures in industry standards and in public-facing materials from companies manufacturing new technologies and equipment.
- Evaluate international agencies and organizations that promote worker health, safety, and well-being for opportunities for joint work and outreach.

Calls for Innovation

Areas of innovation include the following:

- Address institutional limitations of training for immigrant workers and workers belonging to racial and ethnic minority groups.
  - Flynn et al. (2022) suggest OEHS professionals shift from thinking of these workers as "hard to reach" to "hardly reached." That is, instead of asking why these workers are "hard to reach," one should consider "what organizations need to do to develop the institutional capacity to more effectively work with an increasingly multicultural and diverse workforce" (p. 4).
- Provide training and skill development to workers who may be displaced by technology, such as AI, robotics, or automation, so they can be better prepared to perform other work.
- Improve OEHS training:
  - Identify and implement strategies to address training barriers that prevent OEHS professionals from obtaining continuing education to stay current.
  - Take advantage of resources and learning opportunities, including conferences and seminars, as well as in-person and online training and courses. This may include professional training resources, such as:

> » The Occupational Hygiene Training Association (OHTA), the National Safety Council (NSC), and others.
>
> » Professional organizations, such as AIHA, ACGIH, the American Society of Safety Professionals (ASSP), and others.
>
> – Utilize professional and training resources to stay current on new and developing technologies and the risks they may pose to workers.

Next Steps: Progress and Future Directions in Research, Education, Practice, and Policy

- Conduct regular outreach using various methods and technologies to inform workers and management of the importance of upcoming training and the need for feedback to further improve training.

- Conduct benchmarking to see what strategies others in the same organization or in other organizations have successfully implemented to improve the quality and reach of their training.

- Identify, evaluate, and share:
  - Factors that are facilitators and barriers to including foundational competencies that ensure job-specific safety skills as part of work readiness skill-building.
  - New, practical, outcomes-focused learning and retraining methods for workers displaced by new technologies to prepare for future opportunities and help offset any psychological or other harm experienced due to job loss.
  - Tailored and integrated skill-related tools and resources based on job type, occupation, and industry to find impactful long-term solutions, especially for workers at increased risk of safety and health hazards, such as younger or older workers, workers with disabilities, and workers in nonstandard arrangements.

- Incorporate best practice guidance on essential skills for safe and healthy future work into the curricula of existing and new education, training, and skill-building programs, in consultation with:
  - Employers.
  - OEHS and allied educators and professionals.
  - Academic institutions.
  - Professional and trade associations.
  - Labor unions and trade schools.
  - Regulatory agencies.
  - State and local health departments.

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