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RESEARCH ARTICLE

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Preparing the occupational safety and health workforce for future disruptions

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Abstract

Background: Despite some emerging lessons learned from the COVID-19 pandemic, evidence suggests the world remains largely underprepared for—and vulnerable to—similar threats in the future.

Methods: In 2022, researchers at the US National Institute for Occupational Safety and Health (NIOSH) led a team of volunteers to explore how future disruptions, such as pandemics, might impact work and the practice of occupational safety and health (OSH). This qualitative inquiry was framed as a strategic foresight project and included a series of activities designed to help better understand, prepare for, and influence the future.

Results: Findings from a thorough search for indicators of change were synthesized into nine critical uncertainties and four plausible future scenarios. Analysis of these outputs elucidated three key challenges that may impact OSH research, policy, and practice during future disruptions: (1) data access, (2) direct-to-worker communications, and (3) mis- and dis-information management.

Conclusions: A robust strategic response is offered to address these challenges, and next steps are proposed to enhance OSH preparedness and institutionalize strategic foresight across the OSH community.

KEYWORDS

alternative futures, communication, data access, disinformation, misinformation, scenarios, strategic foresight, sudden disruptions

1 | INTRODUCTION

The effects of the COVID-19 public health crisis have been, and continue to be, profound for work and working people. The immediate consequences of the pandemic—which included changes such as new workplace safety and health requirements, mandatory remote work arrangements, reduced working hours, and even unplanned furloughs or terminations—were unexpected, abrupt, and significant for workers worldwide.[1–3] Though domestic and international infection rates declined and protection against circulating variants of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) improved in 2022,[4,5] global experts agree that COVID-19 caused by SARS-CoV-2 will have lasting implications for workers.[2,6–10] In addition, there is evidence that viral respiratory pandemics more severe than COVID-19 are possible in coming years.[11] Unfortunately, a recent assessment of health security capabilities data from 195 countries provides evidence that under-preparedness for the arrival of pandemics and similar disruptive events is common around the world.[12]

Chronic and widespread unreadiness for the future leaves us susceptible to the adverse effects of a wide variety of sudden

disruptions. While pandemics are one example, other sudden disruptions include noncommunicable public health emergencies; terrorist attacks, cyberattacks, and war; power outages and major industrial or engineering accidents; and natural disasters such as earthquakes, floods, hurricanes, heat waves, deep freezes, and wildfires. These abrupt disturbances can significantly alter or interrupt routine activities, including work and jobs, with little advanced warning. Remaining unprepared for their occurrence places the safety, health, and well-being of working people, their families, and their communities at risk. Due to the seriousness of their consequences, many of these disruptions have been identified as critical challenges and threats for the US to consider as part of national strategic planning efforts.[13]

The occupational safety and health (OSH) community would be well-served to follow suit and reflect on how best to enhance OSH readiness to protect worker safety and health during such periods of future disruption. During the COVID-19 pandemic, many OSH professionals saw their roles expand in unanticipated ways to include responsibilities for maintaining business continuities, enhancing organization and individual resilience, assessing and controlling emerging and novel risks, disseminating trustworthy information, and determining how to manage mental health issues in the workplace.[14] In addition, it has been argued that the underrepresentation of OSH perspectives in other public health systems led to reductions in the efficacy of control and assessment efforts early in the pandemic response.[15] Developing OSH plans for the future that effectively address such lessons learned from the COVID-19 pandemic and other disruptive events from recent years may enhance OSH readiness for future pandemics and disruptions when they arrive. In contrast, failing to incorporate such strategies into OSH planning may leave researchers and practitioners—and the working people they serve—even more vulnerable to and underprepared for the adverse health, safety, and well-being impacts of future disruptive events.

Guided by its mission "to develop new knowledge in the field of OSH and to transfer that knowledge into practice,"[16] the National Institute for Occupational Safety and Health (NIOSH), a US federal research agency, is well-positioned to help address this vulnerability of underpreparedness. In recent years, NIOSH has invested resources to build capacity in strategic foresight, a futures-oriented practice that helps individuals and organizations understand, prepare for, and influence the future.[17] At its core, foresight involves identifying, assessing, and monitoring weak and early signals of coming change.[18] These activities are designed to help us answer the important question of "what if?," rather than trying to predict "what's next?."[19] When preparing for periods of potential instability and disruption, the forward-to-the-future vantage point offered by the practice of foresight can serve as a helpful complement to traditional strategic planning efforts, which tend to rely on historical data and assume the future will be a stable and linear extrapolation of the past.[20] In this way, exercises in foresight can expand not only how people think about the future, but also how they begin developing and implementing plans to achieve preferred outcomes and avoid undesirable ones.[18]

A growing body of qualitative (e.g., case-based, anecdotal) and quantitative (e.g., longitudinal analysis) evidence demonstrates a link between foresight and positive organizational outcomes, including improved performance, enhanced innovation, and increased preparedness for future risks and issues.[21–23] Understanding the value of foresight in helping organizations achieve "futures readiness," the NIOSH Office of Research Integration assembled a team of volunteers to conduct a foresight project in early 2022. The purpose of the qualitative Sudden Disruptions Foresight Project (SDFP) project was to explore how sudden disruptions might impact work the future practice of OSH. The SDFP was not an investigation rooted in traditional OSH surveillance or risk assessment methods, where the quality of the research is defined by its reliability, validity, generalizability, or replicability. Instead, this qualitative study aimed to complement empirical OSH efforts by combining structured information-gathering efforts with creative approaches to communication to take a forward-looking view of the future and help inform decision-making, shape strategy, and identify new opportunities for OSH.

As is true for scientific exploration in many fields, there has been a growing call for transdisciplinarity in strategic foresight.[24] A transdisciplinary foresight project team allows differing viewpoints to combine and generate multifaceted and multidimensional future scenarios. Having input from team members with expertise in different but related areas can also enhance the richness of the analysis of the generated scenarios. The SDFP team members, identified in Supporting Information S1: Appendix A of the supporting information for this manuscript, were affiliated with NIOSH and the University of Houston and maintain a diversity of expertise in advanced technologies, the future of work, health communications, injury prevention, OSH policy and regulations, and strategic foresight.

The remaining sections of this paper describe SDFP activities and findings. We conclude by identifying opportunities for broader OSH community engagement in the foresight process to institutionalize futures thinking and enhance OSH readiness for future disruptions.

2 | MATERIALS AND METHODS

2.1 | Foresight framework for OSH

The activities of the SDFP were determined by the NIOSH Human Research Protections Office to constitute non-research public health surveillance under 45 CFR 46.102(1)(2). The SDFP was guided by the Foresight Framework for OSH depicted in Figure 1, which is an OSH-specific adaptation of the University of Houston's internationally recognized Framework Foresight.[25] Progressing through the framework consists of working through a sequence of six interdependent action-oriented stages, where the outputs from each stage serve as critical inputs that inform the activities in the next stage. The domain description produced in Stage 1, for example, serves as a key guide that frames the scan for signals of change in Stage 2. The signals located and coded in Stage 2 then become a critical input to the development of future scenarios in Stage 3, which become the source material for identifying the implications and options in Stage 4 that are implemented and monitored in Stages 5 and 6. To ensure all work within the framework is harmonized, users

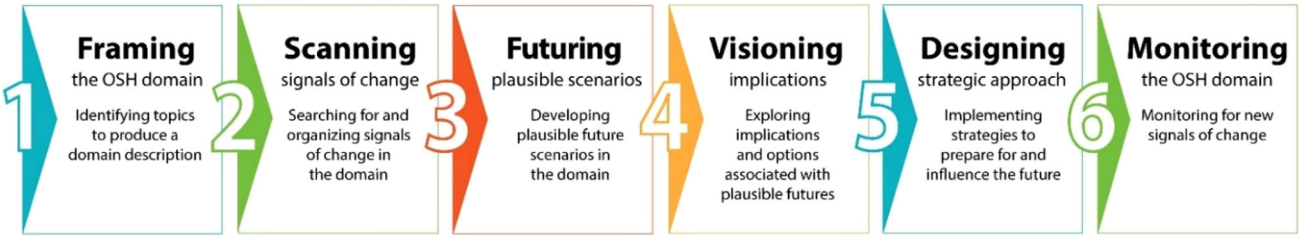

FIGURE 1 Foresight framework for OSH, first published in Streit et al. and available online.[26,27]

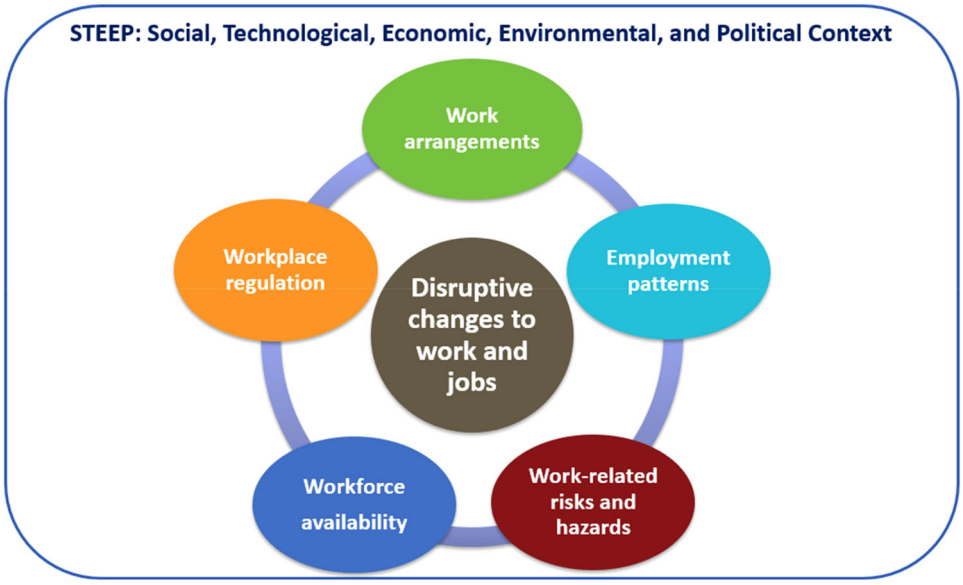

FIGURE 2 Domain map developed for SDFP, which organizes the main topic of "disruptive changes to work and jobs" into five primary topics. SDFP, sudden disruptions foresight project.

are further encouraged to engage in constant back comparison of newly-generated outputs with those produced during previously-completed stages. This provides the user an opportunity to critically reflect on the collective of completed work and determine if any stages require further expansion or refinement before advancing to the next stage in the framework.

Together, the six stages are designed to yield a set of evidence-based scenarios, a comprehensive analysis of the implications and impacts of those scenarios, and a responsive course of future actions. The products generated by the Figure 1 framework are meant to serve as forward-thinking inputs that can help inform strategic planning efforts and other research and practice activities. Additional details on the background and mechanics of the framework, as well as evidence from a previous application to explore alternative futures for OSH, are available elsewhere.[26–28]

2.2 | Framing the domain

According to the Foresight Framework for OSH (Figure 1), the first stage of our work involved *framing* the domain of interest. The major products of this stage included an organized domain map, demarcated time horizons, and a current assessment of relevant conditions, interest groups, and events.

2.2.1 | Domain map

The main domain (subject) of the SDFP was broadly defined as "disruptive changes to work and jobs." The supporting domain map, depicted in Figure 2, further organized this domain into five primary characteristics of work and jobs that might be impacted by disruptive changes: work arrangements, employment patterns, work-related risks and hazards, workforce availability, and workplace regulation. Each of these topics was further defined by a list of specific subtopics, provided in Figure 3. To complete the map, the defined domain was also situated within its broader Social, Technological, Economic, Environmental, and Political (STEEP) context. Considering STEEP factors as the domain "backdrop" helps to ensure a variety of influential external factors, trends, norms, and values are appropriately and sufficiently considered throughout the duration of the project.[29] This can be particularly important for explorations of

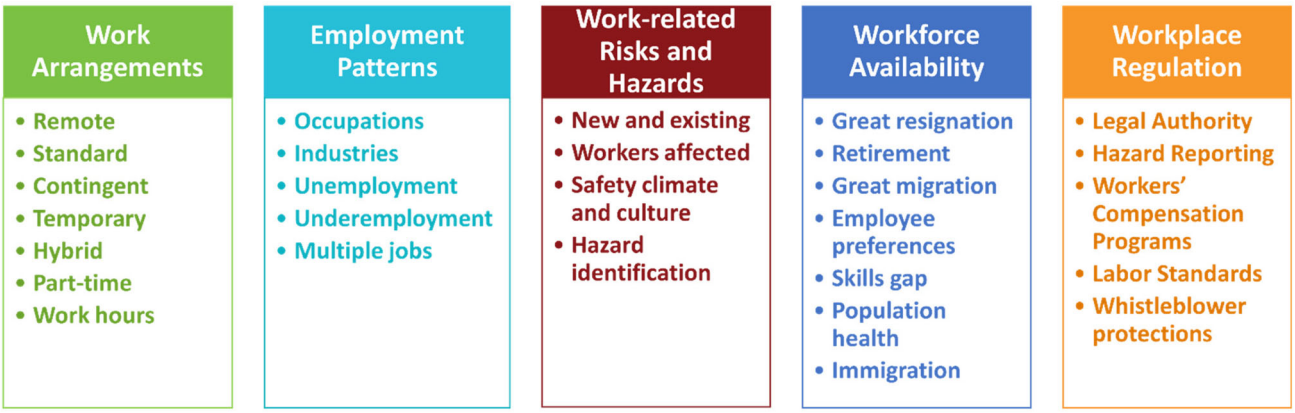

FIGURE 3 Subtopics developed for SDFP, which further define each of the five primary domain topics from Figure 2. SDFP, sudden disruptions foresight project.

sudden disruptions, as a number of STEEP factors have been identified as having a significant impact on individual, organization, community, and government responses during a variety of public health emergencies.[30–33]

2.2.2 | Time horizons

Prominent theoretical physicists assert "the future" refers to an indefinite amount of time beyond the current moment.[34] The practice of foresight, however, requires this unbounded future be described in such a way that it can be meaningfully compared and contrasted with the present.[35] To satisfy this requirement, we followed a common foresight technique and defined the future by three distinct horizons known as the near, mid-, and far-term future.[36] Horizon 1 (H1), the near-term future, represents the current way of doing things within domain. Horizon 3 (H3), the far-term future, represents a new, more effective way of operating within the domain. Between H1 and H3 is Horizon 2 (H2), a midterm period of significant change and transition.

Generating and evaluating short- and longer-term futures that are significantly different from the H1 status quo can facilitate early and useful planning for future conditions that may arrive rapidly and without much warning. Well before the onset of COVID-19—as far back as 2008—futurists and foresight practitioners recognized the need to conduct disaster response exercises to enhance planning and preparedness for the possibility of future large-scale disease outbreaks.[37,38] Though their results were not widely adopted, these exercises offered insights into the supports and resources required for survival through a significant widespread respirable disease; identified key issues and challenges that could exacerbate the economic and societal consequences of a large-scale pandemic; and generated a series of recommendations to address critical preparedness gaps with respect to the availability of vaccines and other therapeutics, the continuity of safe and effective travel and business operations, and public health readiness to combat widespread mis-, dis-, and mal-information.[37–39] More recently and specific to OSH, NIOSH conducted a strategic foresight project to explore four scenarios of plausible futures for OSH ranging 5–16 years into the future.[28] This project yielded a set of recommendations to address key issues for OSH research and practice according to a phased near-, mid-, and far-term approach, noting that implementation can and should occur based on opportunity and need.[28] Such flexibility allows organizations to adjust the timing along which responsive actions are pursued, particularly if the mid- or far-term future states arrive sooner than initially anticipated.

In the context of sudden disruptions and OSH, H1 might be conceptualized as the practice of OSH in response to COVID-19. H2 would be an upcoming period of transition and innovation for the practice of OSH, brought on by the next several disruptions; and H3 would be a transformation that better prepares OSH to respond to, and be resilient against, future disruptions. Though not yet the prevailing approach, there are glimpses of this H3 in the present. Recent recommendations to significantly expand the focus of OSH[40,41] are one current signal of potential long-term transformation for OSH. This conceptual expansion challenges us to recognize, explore, and address the interactive nature of diverse worker health and well-being outcomes that are complexly affected by personal, family, occupational, community, and societal risk factors across the entire working life continuum.[40] This more holistic view of OSH risk factors and outcomes may enhance OSH capacity to prepare for and respond to future disruptions.[41]

When designing a foresight project, the time-based definitions applied to the near-, mid,- and far term futures are flexible.[36] They are most useful, however, when aligned with relevant planning or business cycles.[42,43] For SDFP, we defined the horizons according to NIOSH strategic planning cycles. We aligned H1, the near-term future, with the current NIOSH strategic plan (present to 2026); H2, the midterm future, with the next 10-year planning cycle (2027–2036); and H3, the far-term future, with subsequent cycles (2037 and beyond).[44]

2.2.3 | Current assessment

Exploration of the SDFP domain began with a current assessment, which describes the recent history and present-day context of the domain in H1.[45] Completing the current assessment consisted of summarizing relevant conditions, key interest groups, and examples of major 21st century disruptions that clearly required an OSH response. The results of this assessment are provided in Table 1. While this

TABLE 1 Current assessment of sudden disruptions and the OSH response.

Assessment category	OSH response to sudden disruptions
Current conditions	Response to the COVID-19 pandemic demonstrated OSH ability to respond to a major disruption to the US economy, employers, workers, and workplaces.[46–48] Throughout COVID-19, NIOSH was a key collaborator and information source for a variety of audiences, including federal, state, local, and territorial public health agencies; federal and state regulatory agencies; labor; and industry. NIOSH contributions helped to identify pandemic impacts for work and working people, develop individual and organizational intervention and prevention strategies, and communicate accurate and timely information to the public.[49] Key factors and gaps impacting the OSH response to disruptions are diverse. Examples include: *Automation*: Automation provides tools to improve data analysis and communication. OSH experience with these tools is expanding, which may improve responses to future disruptions.[50] *Demographics*: Women and ethnic minority groups are underrepresented in the OSH community. This does not align with the diversity of the US labor force and may limit the efficacy of OSH communication and research translation efforts during disruptions.[51] *Nature of work*: There are gaps in OSH understanding of the ever-diversifying tasks, hazards, work arrangements, and necessity (e.g., "essential work" status) of jobs performed by the US labor force. Though OSH continues to expand its research and practice efforts to reach workers in the new economy, this may leave limited response capacity during disruptions.[52] *Worker protections*: The traditional OSH approach relies on standards, regulation, and the power of organized labor, which have declined in recent years. If this trajectory continues, this may limit OSH capacity to respond to disruptions.[53] *Power dynamics*: Overall declining trust in government, combined with questions regarding federal authority and effectiveness in enacting public health policy during COVID-19, may limit OSH community ability to respond to disruptions.[54,55] *Blurred boundaries*: Worker and employer perceptions of the hybrid environment confounds reporting and categorizing of hazards, which may limit OSH communication following disruption and reduce research-to-practice (R2P) efficacy.[56] *Career trajectories*: Increasing complexity in employment arrangements and the working life continuum (e.g., job and career changes, multi-employment, self-employment, periods of underemployment and unemployment, etc.) challenge the efficacy of traditional OSH data collection approaches. Limited quantity and quality of OSH research and evidence hinders the ability to respond to changing hazards during disruptions.[52]
Key interest groups	US Centers for Disease Control and Prevention [CDC] Emergency Operations Center Other US federal agencies, such as the Federal Emergency Management Agency [FEMA], the Department of Homeland Security [DHS], and the Occupational Safety and Health Administration [OSHA] OSH professional societies Labor organizations Industry associations Companies Workers State, local, and territorial public health agencies Training organizations OSH community of researchers and practitioners
Exemplar 21st century disruptive events with OSH impacts	2001: 9/11 terrorists and anthrax attacks 2004: Haiti earthquake 2005: Hurricane Katrina 2009: Avian Influenza A [H1N1] 2011: Japan earthquake and tsunami 2010: Deepwater Horizon Oil Spill 2010: Haiti earthquake 2013: Moore, Oklahoma tornado 2017: Hurricane Maria 2017 to present: Opioid epidemic 2020 to present: COVID-19 pandemic 2022 to present: Russian invasion of Ukraine

Abbreviation: NIOSH, National Institute for Occupational Safety and Health.

exercise was not intended to provide a comprehensive or systematic review of the current state of OSH, it established a baseline relationship between disruptive changes and the OSH response.

The current assessment highlighted salient 21st century OSH successes when responding to disruption, particularly during the COVID-19 pandemic. At the same time, the results also provided insights into noteworthy gaps and challenges that may impede the success of OSH efforts during future disruptions. These included factors related to automation, data access, communication, OSH workforce demographics, the changing nature of work, an overall decline in worker protection standards and regulations, a shift in power and trust dynamics for the federal government, the continued blurring of the boundaries between work and nonwork life arenas, and an increasing complexity in career trajectories and employment arrangements.

2.3 | Research

After establishing the current baseline, we moved to the second stage of the Foresight Framework for OSH and shifted our focus to the future. Activities in this stage revolve around research known as *scanning* (Figure 1, Stage 2), which involves reviewing a variety of information sources to understand how the future might be different from today.[25] Information sources consulted during scanning can range from traditional refereed publications and major surveillance systems to government and stakeholder reports, legislative records, trade and technical journals, newsletters, monographs, blogs and other thought pieces, mainstream and fringe media, general internet searches, and interviews with experts.[57,58] For SDFP, we completed a thorough scan of print and online sources and conducted a series of key informant interviews to gain deeper insights into the future of sudden disruptions and their potential impacts to the practice of OSH over time.

2.3.1 | The scan

The SDFP domain map topics and subtopics presented earlier in Figures 2 and 3 served as key terms to guide our in-depth search and review of print- and internet-based resources. Over the course of five weeks in February and March 2022, the team scanned for information on sudden disruptions and their potential impact to work, working people, and the practice of OSH in the future. To ensure adequate coverage across the domain, one team member was assigned the primary "scanner" for each topic identified in the Figure 2 domain map. All scanners also agreed to search for signals more generally associated with sudden disruptions that may have an impact to work, working people, or OSH in the future. Before beginning the scanning exercise, the team received a refresher training on effective scanning for strategic foresight. In addition, each scanner was provided a structured worksheet to help facilitate the organization and cataloging of their scanning results. The following fields were included in the worksheet and completed for each reference found during the scan:

- Title of the scanning reference;
- Date of publication;
- Source for the scanning reference (e.g., URL, print media source title);
- Main topic from the Figure 2 domain map supported by the reference;
- Subtopic from Figure 3 supported by the reference;
- Brief description of the key takeaways from the reference;
- Horizon in which the suggested change(s) will occur (H1, H2, or H3);
- Plausibility of the suggested change(s) occurring; and
- Current preparedness to manage potential OSH outcomes associated with the change(s).

The purpose of the scan was not to identify every possible trend that will influence the future, but rather to detect potentially important and plausible developments that *may* have a critical impact over time and for which the OSH community is not fully prepared. These developments included known trends, persistent problems, risks and threats, and early indications of new changes only starting to take shape.[59] The exploratory scan was meant to provide a sense of "what is constant, what may change, and what is constantly changing" with respect to disruptions and the OSH response.[60]

The scanners met weekly to discuss the signals they had collected. The scanning exercise concluded when the scanners agreed they had reached saturation and were no longer finding novel information in their assigned topic area, and the team collectively agreed there was adequate representation of signals across all domain topics.

Through this activity, we located and catalogued 241 relevant signals of change. These signals all related to disruptions that may occur and the impacts these disruptions may have to work, jobs, and OSH across H1 (strong and important signals we should continue to consider as we move into the future), H2 (moderate signals suggesting how options may resolve in the midterm future), and H3 (weak or early signals of new changes that may emerge over the longer-term future). The results of this exercise became the official "scanning library," or organized repository of signals of future change, for SDFP. A summary of the scanning library contents is provided in Table 2. The distribution of more strong signals, fewer moderate signals, and even fewer early signals of change is consistent with both the results of previous scanning efforts conducted by NIOSH[28] and scanning overviews provided by international foresight experts during foresight training classes attended by NIOSH staff members.[61,62]

2.3.2 | Key informant interviews

Interviews are a common technique used in foresight to help detect key trends and emerging issues.[63–65] Best practices in strategic foresight indicate those who are interviewed need not necessarily be futurists or foresight practitioners; rather, the interviewees should be thought leaders, decision-makers, and other key interested parties

TABLE 2 Summary of signal types captured in the scanning library, organized by domain topic ($N = 241$).

Domain topic	H1 strong signals	H2 moderate signals	H3 early (weak) signals	Total
Work arrangements	14	7	6	27
Employment patterns	10	12	6	28
Work-related hazards and risks	11	6	5	22
Workforce availability	21	8	11	40
Workplace regulation	21	8	2	31
STEEP	32	16	2	50
Sudden/rapid disruptions (general)	19	17	7	43
Total	128	74	39	241

Abbreviation: STEEP, social, technological, economic, environmental, and political.

who are well-versed and active in the domain of interest and who maintain strong connections to the client organization.[25,66] As a complement to the scan, we conducted a series of semistructured key informant interviews with 12 NIOSH senior leaders and scientists. These individuals represent the field of OSH dating back to the establishment of the US Occupational Safety and Health Act of 1970[67] and maintain expertise in one or more of the domain topics identified in Figure 2.

The 30 min one-on-one conversations were held virtually using the Zoom for Government (Zoomgov) platform in April and May 2022. In each session, a SDFP team member with formal training in strategic foresight and OSH research experience served as the interviewer and posed a series of predetermined questions (see manuscript Supporting Information S1: Table S1) that had been developed according to the University of Houston's modernization of the foresight interview approach made popular by the Global Business Network foresight consulting firm in the 1990s and early 2000s.[68] The template for this interview approach consists of eight open-ended futures-oriented questions designed to encourage interviewees to reflect and think strategically about key issues, opportunities, and challenges for the past, present, and 10-year future of the project domain of interest. For the SDFP, the questions were tailored to solicit subject matter expert (SME) opinion on: (1) successes and failures in preparing the OSH workforce for past sudden disruptions; and (2) the trends, decisions, and obstacles that may impact how we prepare the OSH workforce for future disruptions. To ensure they felt adequately prepared for the interview, all key informants received an advance copy of the interview questions. The interviewer asked unscripted probing questions, as needed, for clarification purposes during each interview. This approach aligned with best practice standards for conducting interviews designed to inform scenario-based planning activities.[66]

Two SDFP team members with formal training in strategic foresight and OSH research experience analyzed the interview transcripts autogenerated by Zoomgov using NVivo 12 Qualitative Research Data Analysis software.[69] Because there was no preexisting coding frame for sensemaking of the data, they followed the inductive and iterative data-driven coding approach described in Braun and Clarke's qualitative framework for identifying themes from the SME responses to the futures-oriented SDFP interview questions.[70] This framework includes six phases: becoming familiar with interviewee responses, generating initial codes, clustering codes into themes, reviewing themes, defining themes, and reporting the results. The coding process for this project also involved a constant comparison of the emerging themes to the established time horizons (H1, H2, and H3) for relevance to the near-, mid-, and far-term futures. The final list of 17 themes extracted from the futures-focused interviews, along with the number of interviews in which each theme arose, is presented in Table 3. The specific concepts from the futures-focused interviews that underly each theme are available in the supplemental materials for this manuscript (see Supporting Information S1: Table S2).

The most common themes were *relationships*, *adaptability*, *mechanisms for building OSH capacity*, *issues conveying information*, and *organization of work*. Interview content related to the theme of relationships included comments on the importance of building and sustaining connections with partners and collaborators in academia, industry, organized labor, other public health agencies, and other governmental entities. Adaptability comments focused on concepts such as organizational agility, rapid readiness and improved response times, resilience, and contingency planning. Mechanisms for building OSH capacity identified by the interviewees included building a new reserve OSH workforce and cross-training and upskilling OSH professionals. Interviewees also recommended developing integrated communication and dissemination strategies and finding ways to effectively overcome public mis- and dis-trust as essential to conveying information during disruptions. Organization of work challenges, such as new work arrangements and organizational structures, were also discussed in most of the interviews.

2.3.3 | Scanning synthesis

The full SDFP team compared the scanning and interview results to identify higher-level common threads captured by both data

TABLE 3 Final list of themes from futures-focused key informant interviews ($N = 12$).

Theme	N
Relationships	12
Adaptability	12
Mechanisms for building OSH capacity	11
Issues conveying information	10
Organization of work	10
Potential future disruptions	9
Research priorities	9
New technologies	7
Data quality	7
Leadership	6
IT infrastructure	4
New risks and hazards	4
Policy and regulation	2
Politicized public health	2
Threat perceptions	2
Innovation	1
Faulty assumptions	1

Abbreviation: OSH, occupational safety and health.

collection methods. We specifically looked for threads representing factors that will impact the practice of OSH in important but unknown directions during future disruptions. This data synthesis process involved two steps. First, the recurring threads were articulated as drivers of disruptive change. Then, those drivers were reframed as key uncertainties about the future practice of OSH during disruptions.

Drivers of change

Drivers of change are factors that will affect or shape the future of the domain of interest.[25,71] Using the qualitative data analysis process described by Saldaña, we first extracted the key concept from each of our scanning data and interview themes.[72] We next used the key concepts to organize the scanning data and interview themes into 15 clusters defined by data-driven connections. Each of these 15 clusters was then articulated as a unique driver of disruptive change.

Each SDFP team member used a 3-point scale to independently evaluate their feelings of uncertainty about how each driver might unfold across the future, where 1 = highly uncertain, 2 = somewhat uncertain, and 3 = mostly predetermined. The independent evaluations were averaged to calculate a final uncertainty score for each driver. The list of 15 drivers, along with their definitions and uncertainty scores, is ordered in Table 4 by degree of uncertainty (highest to lowest). The core concept of each driver is noted by bold text in the "Definition" column.

The drivers coalesced around four central topics related to sudden disruptions and the OSH workforce. Four drivers addressed concepts related to the future of OSH capacity: *Fast education*; *Who's really in charge?*; *Break from tradition*; and *The self-reliant career*. Five drivers focused on the future organization of work and jobs: *The great reshoring*; *Human is more human*; *Growth of automation*; *Tech-cessibility*; and *Speed kills*. Four drivers described changes that may affect the psychosocial risks associated with work in the future: *The big (social) rip*; *Bye bye boundaries*; *Diversity as a safety issue*; and *Systemic stress*. The remaining two drivers—*Reformation of the labor movement*, and *A struggle to support*—related to the future of worker protections.

Key uncertainties

The full SDFP team used the 15 drivers as the basis for constructing key uncertainties, which are high-impact issues, typically framed as questions, that will influence the domain of interest in undetermined directions.[43] To generate uncertainties for SDFP, we first set aside the four drivers from Table 4 that were perceived to be relatively certain or predetermined (i.e., those with uncertainty scores above 2.0) and focused on the 11 drivers classified as somewhat-to-mostly uncertain (i.e., those with uncertainty scores between 1.0 and 2.0). Of these, the *Bye bye boundaries* and *Tech-cessibility* drivers did not advance to uncertainty development. All SDFP team members agreed these two drivers will evolve in a known (increasing) direction over time, albeit along unknown trajectories.

We developed the remaining nine drivers into key uncertainties by reframing each of their bolded core concepts from Table 4 into a yet-to-be-answered question. For each resulting question, we constructed a pair of polarized response options (Response A and Response B). The final set of key uncertainty questions is presented in Table 5. The uncertainties are presented in the same order and identified by the same numbers as their originating drivers from Table 4. The *1. Training the OSH workforce* uncertainty in Table 5, for example, is derived from the *1. Fast Education* driver in Table 4; and the *9. Remote economy* uncertainty in Table 5 is derived from *9. The self-reliant career* driver in Table 4.

The final list of key uncertainties raised critical questions about the future of OSH training programs, organized labor, public trust in government, the global supply chain, regulations, technology and automation, health and safety management, and health equity. The proposed responses for each uncertainty question were intentionally written to represent opposing and extreme outcomes for each uncertainty topic, recognizing the actualized future could fall anywhere along the resulting continuum.

2.3.4 | Scenario building workshop

The SDFP used the final list of key uncertainties from Table 5 as the primary inputs to its *futuring* efforts (Figure 1, Stage 3). The goal of futuring is to systematically think about and plan for the future and its possible outcomes.[73] The primary product of this stage of the foresight process is a set of complementary scenarios, or stories with

TABLE 4 Drivers of disruptive change, listed in descending order of future uncertainty.

Descriptive driver name	Definition (core driver concept is noted in bold)	U[a]
1. Fast education	The lines between what used to be known as on the job training or an internship become the core of **skills-based, rapid readiness and training/retraining programs**, which are funded thru partnerships between schools and leading employers.	1.3
2. Who's really in charge?	**Federal regulation and oversight of OSH are called into question** as administrations change, budgets dwindle, mis- and dis-information politicize public health, and public opinion further divides over the management of public health crises like COVID-19.	1.5
3. Reformation of the labor movement	The renewed focus on worker rights and promise of legislative reform (PRO Act) breathes life into the **modern-day labor movement**.	1.5
4. The great reshoring	Challenges to the reliability of **global supply chain** increase interest in restoring domestic capacity (and workforce) in declined industries.	1.6
5. Break from tradition	As work changes (arrangements, patterns, hazards, technology etc.) **regulatory policy and practice will likely change** with it.	1.7
6. Human is more human	Any **work that cannot be automated** has a renewed focus on "being human" and is undertaken by a diverse labor force supported by partially autonomous technologies.	1.8
7. The big (social) rip	Technological and social trends are **increasing the effective distance between workers and the objects of their work**, their customers, management, and each other.	1.8
8. Growth of automation	**Automation and artificial intelligence** will alter the job market mix and the skills needed to support a new economy. Producing, monitoring, and maintaining these technologies will redefine many industries and existing occupations.	1.9
9. The self-reliant career	Individuals are taking on more responsibility in **shaping their careers** beyond the constraints of a specific job or employer.	2.0
10. Bye bye boundaries	The constant operation of businesses and need to maintain connectivity **breaks down the barriers between personal and professional life**, increasing the need for employer-sponsored work-life benefits and assistance in finding relevant community-based resources and supports.	2.0
11. Tech-cessibility	The **proliferation of highspeed broadband, 5G and accessible hardware** brings online accessibility to more people, nurturing remote work, online business, online education and training, and virtual healthcare.	2.0
12. A struggle to support	Changes in hiring and employment norms complicate the work experience and **challenge existing support and protections systems**, including workers' compensation, other insurance, and benefits offerings.	2.3
13. Speed kills	The **rush to innovate** is outpacing the ability of people and systems to adapt, threatening OSH ability to keep up, and workers to maintain relevancy and cope with the stress.	2.5
14. Diversity as a safety issue	**Changes in workforce demographics**—including age, ethnicity, language, education/skills and more—influence employment projections and portend changes in hazards/risks faced by workers and prevention strategies necessary to address risks to worker safety, health, and well-being.	2.7
15. Systemic stress	New ways of working and the resultant growth in economic disparities **increase stress levels** for individuals, families, and communities.	3.0

Abbreviation: OSH, occupational safety and health.

[a]U, uncertainty score. Scale: 1 = mostly uncertain; 2 = somewhat uncertain; 3 = mostly predetermined.

carefully constructed plotlines that describe a set of plausible futures that are relevant to the domain.[74,75]

Futuring in SDFP followed the matrix method, also known as the 2 × 2 double uncertainty method, to build scenarios describing how sudden disruptions might impact work and working people and shape the practice of OSH. This method was formalized as a scenario-building approach by the Global Business Network.[43] As its name suggests, this scenario development method is constructed around a 2 × 2 matrix. The perpendicular axes are defined by two high-impact, high uncertainty issues defined by polarized outcomes.[76] Four unique scenarios are then mapped into the resulting matrix quadrants.

Scenario building using the matrix method typically involves gathering SME input via workshops.[43] For the SDFP, key informant interviewees (Section 3.2) were invited to participate as SMEs in a virtual scenario building workshop. The workshop was held as two half-day sessions in June 2022, hosted once again on the secure Zoomgov platform. Day 1 began by reviewing and answering questions about the nine key uncertainties displayed in Table 5. The SMEs then engaged in a multiround ranking and review exercise to prioritize the uncertainties based on their perceived importance and degree of uncertainty with respect to sudden disruptions and their impact on the future practice of OSH. Through this exercise, the

TABLE 5 Final list of key uncertainties, with polarized response options.[a]

Uncertainty topic	Key uncertainty question	Response A	Response B
1. Training the OSH workforce	Will the OSH workforce be trained by third parties, such as traditional postsecondary education programs, or will it rely on employer-specific rapid readiness training on the job?	Traditional training	On-the-job training
2. Influence of organized labor	Does the renewed focus on worker rights and legislative reform reinvigorate organized labor, or is it rendered ineffective by opposition and apathy across industries?	Reinvigorated	Rendered ineffective
3. Trust in government	Do government agencies regain their reputation as a trusted source of health information, or does the public turn to individual influencers who become the dominant voice?	Government regains reputation	Individual influencers dominant voice
4. Global supply chain	Will industries restore domestic capacity, or will they become even more dependent on complex and unpredictable international commerce?	Restore domestic capacity	Complex international commerce
5. Regulatory policy and practice	As work arrangements change, does regulatory policy and practice protect the individual worker or industry bottom line?	Individual worker	Industry bottom line
6. Social connectedness	Do advances in technology foster connectedness and productivity, or do they socially isolate workers to a point of diminishing returns?	Tech connects	Tech isolates
7. The human element	As work tasks are continuously automated by more capable technologies, does human labor remain essential or become optional?	Human labor essential	Human labor optional
8. Workforce health and safety	As the workforce becomes more mobile and distributed, does health and safety remain an employer responsibility or does it become an individual responsibility?	Employer responsibility	Individual responsibility
9. Remote economy	Will the remote economy worsen occupational health disparities and inequities, or will it promote equity among a diverse workforce?	Worsens disparities and inequities	Promotes equity

Abbreviation: OSH, occupational safety and health.

[a]Responses A and B in each row represent polarized outcome options for the corresponding uncertainty question.

SMEs ranked *Trust in government*, *Social connectedness*, and *Workforce health and safety* as the top three uncertainties from the list.

Using these top uncertainties, we constructed three possible 2 × 2 scenario matrices that could be used to organize discussion of the longer-term future. The assignment of each uncertainty to either the *X*- or *Y*-axis in each matrix was arbitrary. In Option A, the axes were *Trust in government* and *Social connectedness*. In Option B, the axes were *Trust in government* and *Workforce health and safety*. In Option C, the axes were *Social connectedness* and *Workforce health and safety*. SME discussion of the utility of each resulting matrix option was guided by the following questions:

- Can each quadrant in the matrix be readily named?
- Is each quadrant of the matrix plausible?
- Are the quadrants of the matrix meaningfully different?
- Do the four quadrants of the matrix resonate with the SDFP project domain (Figure 2) and suggest real challenges we may face to prepare the OSH workforce for sudden disruptions?

Through this discussion-based assessment exercise, the SMEs selected the matrix defined by *Trust in government* and *Workforce health and safety* as the best choice for building scenarios because it was the option that: (1) most strongly resonated with the concept of disruptive changes to work and jobs, and (2) most clearly suggested future OSH challenges that will be relevant across the greatest number of industry sectors. The basic structure of this final scenario matrix is presented in Figure 4.

On Day 2 of the workshop, the SMEs broke into four discussion groups and began mapping out how all nine uncertainties from Table 5 might play out in each quadrant (Scenario A, B, C, and D) of the Figure 4 matrix. The groups also considered whether the *Bye bye boundaries* and *Tech-cesssibility* drivers from Table 4 that had not been developed into uncertainties should be mapped into any of the quadrant scenarios. Each group was provided a worksheet to organize and record their mapping discussion for the assigned scenario. A sample of this worksheet, which provides an organizing structure for identifying and describing in detail how relevant drivers and uncertainties unfold within a given scenario, is provided in the supplemental materials for this manuscript (see Supporting Information S1: Table S3). After 2 h of small group work, the full group reconvened to share findings and debrief. As needed, adjustments were made to each scenario map during the full group discussion to ensure the four resulting stories were distinctly different from one

another. The final results of this SME scenario mapping exercise are summarized in the supplemental materials for this manuscript (see Supporting Information S1: Table S4).

3 | RESULTS

The outcomes of the June 2022 SME workshop were used as the basis for developing a scenario story in each of the four matrix quadrants. The SDFP team members noted in Supporting Information S1: Appendix A of the supporting information for this manuscript, who maintain expertise in both the matrix axes topics and foresight methods, built upon the four scenario maps described in Supporting Information S1: Table S4 of the supporting information for this manuscript to craft full narratives of 400–600 words each for Scenarios A, B, C, and D. This exercise consisted of finessing the input from the scenario workshop small discussion groups—which had been captured in writing via the mapping worksheets—into structured sentences connected by appropriate transitionary language with a unified writing style and prose voice. These narratives were produced through a series of individual and group writing sessions, then vetted with all other SDFP team members before being considered "final."

3.1 | Sudden disruption scenarios

Table 6 summarizes the final four scenarios constructed within the 2 × 2 matrix depicted in Figure 4. Full abstracts for these possible futures are provided in Sections 3.1.1. through 3.1.4.

3.1.1 | Trusted partnerships

By releasing timely, transparent, and accurate messaging the public can understand, the US government regains its reputation as a trusted source of health information. A strong regulatory landscape provides the needed backdrop for federal, state, and local governments to support and enforce OSH requirements, and there is widespread acceptance of OSH as an essential employer responsibility. New collaborations are formed to address OSH issues for workers across a variety of employment arrangements. Technological advancements support effective information dissemination among a global OSH community, but innovation leaves OSH struggling to meet industry demand and hit what feels like an always-moving target.

3.1.2 | The multi-polar world of OSH

The US government's continued inability to respond effectively to crisis further erodes public trust. Social media use leads to the rise of super-influencers, who become the primary movers of public opinion. Corporations and unions alike appeal to these individuals to advance their views and values, and their success is based on the power of the purse. Amid this shift in the landscape of "information," the courts retain the General Duty clause and little else pertaining to OSH. Outdated OSH laws and regulations are forgotten or discarded, and efforts to reduce work-related risks and hazards hinge primarily on the ability of a select few to persuade industry leaders and the courts of the importance of individual workforce safety, health, and well-being issues.

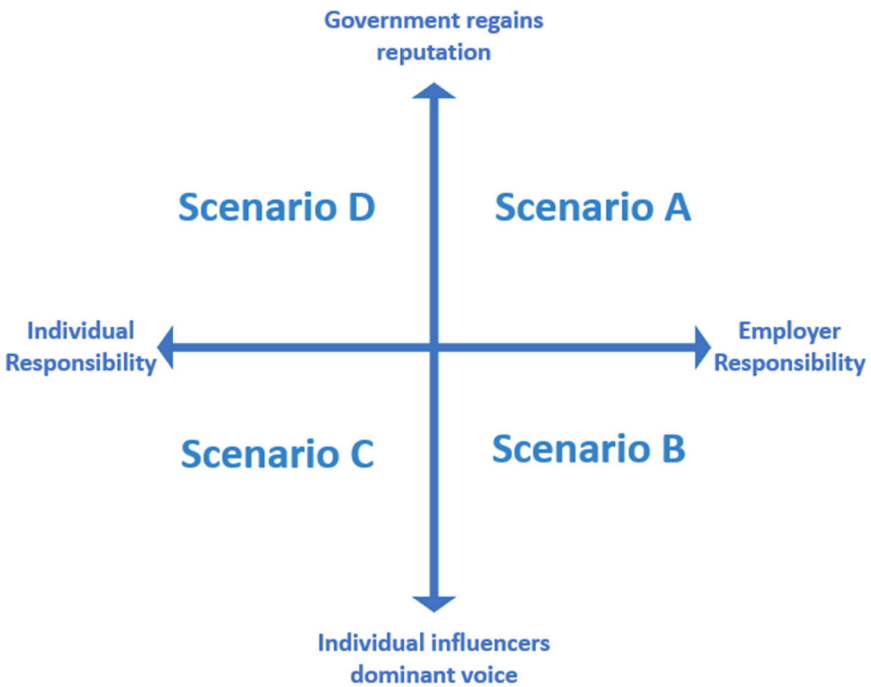

FIGURE 4 Final 2 × 2 scenario-building matrix developed for SDFP. The *X*-axis was defined by the workforce health and safety uncertainty, and the *Y*-axis was defined by the trust in government uncertainty. Together, they defined the quadrants in which unique scenarios (A, B, C, and D) could be constructed. SDFP, sudden disruptions foresight project.

TABLE 6 Summary of four futures developed for SDFP, in which sudden disruptions have impacted work and jobs and shaped the practice of OSH.

Scenario	Title	Description
A	Trusted partnerships	The US Government regains its reputation as a trusted source of health information and works closely with employers, who remain responsible for the health and safety of their workforce and workplace.
B	The multi-polar world of OSH	Both employers and the government lobby individual influencers, who have become inconsistent centers of workplace health and safety information. Mixed messaging perpetuates inconsistent application of the General Duty Clause of the Occupational and Safety and Health Act of 1970.
C	Race to the bottom	Individual influencers have replaced the government as the trusted source for health information and individuals, rather than employers, become stewards of their own health and safety.
D	Rugged individualism and trustworthy government	Workers in certain sectors thrive under a new regulatory framework while others bear the burden. Employers are liberated from liability, but the government has more resources to pursue health and safety efforts for the general public.

Note: The *X*-axis was defined by the workforce health and safety uncertainty, and the *Y*-axis was defined by the trust in government uncertainty.
Abbreviations: OSH, occupational safety and health; SDFP, sudden disruptions foresight project.

3.1.3 | Race to the bottom

OSH is rendered paralyzed and powerless as the US government has lost status as a trusted source for health information, and OSH training programs struggle to survive. Individual influencers step in to fill the guidance gap and dominate discourse around a variety of topics, including health and well-being. Workers find themselves lost in a "wild, wild west" of conflicting, unregulated, and often inaccurate information. The effects are deleterious for a system where individuals are solely responsible for understanding and meeting their own health and safety needs without OSH regulation or employer-sponsored assistance. As one of the only organized entities advocating for evidence-based OSH, labor unions struggle to find reliable OSH information and products to disseminate to a limited audience. Without oversight or social pressure to invest in worker well-being, businesses race to the bottom to obtain the cheapest labor possible.

3.1.4 | Rugged individualism and trustworthy government

Chains of public health, financial, environmental, and national security crises force dramatic rethinking. A new framework arises where the functional role of the federal government is primarily to develop guidelines and recommendations. Regulatory authority is retained for limited few issues, which do not include OSH. Worker protections—including those related to health, safety, and the right to unionize—gradually vanish. Success in this new role rebuilds general confidence in government as a trusted source of information, and workers have access to evidence-based recommendations on how to effectively manage their safety, health, and well-being in this deregulated world of work. Unfortunately, the benefits are not evenly shared. Workers in some sectors and occupations face a far greater degree of risk, exacerbating occupational health inequities between worker groups.

3.2 | Extracting practical implications from the scenarios

After the scenarios were constructed, SDFP moved to the *visioning* stage of the framework (Figure 1, Stage 4) to identify the critical issues implied by the four potential futures. Work in this stage focused on Scenarios B, C, and D. Scenario A was excluded from the implications assessment because it represents a relatively utopian world i in which government is a trusted source of public health information and successfully collaborates with industry to advance OSH. Since the OSH community is well-prepared to function in this type of harmonious future, there was no need to focus additional efforts on how to plan for its arrival.

3.2.1 | Visioning workshop

The visioning stage began by reconvening the key informant interview SMEs in a 4 h online Zoomgov workshop in August 2022. As a first activity of the workshop, the SMEs completed a poll to assess the Scenarios B, C, and D in terms of their likelihood (highly unlikely, 50/50, or highly likely) and the current level of NIOSH preparedness for the described future (very prepared, somewhat prepared, or very unprepared). Through this activity, the SMEs identified Scenario B and Scenario C as two futures for which NIOSH is most unprepared. The remaining workshop time was devoted to three additional large group discussion-based visioning activities that delved deeper into these two scenarios. During all the discussion activities, a member of the SDFP team with formal training in strategic foresight took notes that were projected in Zoomgov to the

SMEs. This allowed for on-the-spot revisions to all captured records of the group work. In the first discussion activity, the SMEs spent approximately 1 h brainstorming a short list of four to six key changes implied by each of these two futures. They also collectively projected a series of if–then cascading impacts of each key change for the practice of OSH. In the second discussion activity, the SMEs spent another hour articulating the strategic issues underpinning the changes and impacts derived from the first hour of discussion. In the third activity, the SMEs spent the final hour of the workshop drafting strategic response options for the underlying issues identified during the previous hour of discussion.

3.2.2 | Key strategic issues to preparing OSH for sudden disruptions

The SDFP team spent September 2022 refining the outputs generated by the SME visioning workshop. The SDFP team also repeated the visioning workshop activities described in section 3.2.1 to identify key changes, impacts, and strategic issues for Scenario D.

In total, 11 unique issues that may impact the practice of OSH during periods of disruption were identified across Scenarios B, C, and D. These issues coalesced around the topics of communications, data access, data collection, individualized OSH (i.e., management of OSH at the individual worker level), job changes, worker protections, and workforce retention.

Keeping in mind the SDFP goal of having an OSH workforce that is more prepared for the future, the full SDFP team collectively assessed each issue in terms of the severity of its potential consequence(s) if the issue is left unaddressed (low, moderate, or high) and the degree of known activity already underway to address the issue (very little, some, or a great deal). The five issues presented in Table 7 were identified as having a high degree of negative impact on OSH system preparedness for disruptions if they are left unaddressed. These issues are organized first by the severity of their impact, then by the degree of activity currently underway to address them.

The issues in this list related to the topics of communication (mechanisms and content), data access, individualized OSH, and research support mechanisms. It is worth noting that each of these issues was also represented in some form among the gaps and challenges uncovered in the earlier baseline current assessment (Table 1). This connection between the present and the future reinforced the importance of acting now to address these issues as part of efforts to prepare the OSH workforce and plan for potential forthcoming disruptions.

4 | RECOMMENDATIONS

4.1 | Strategic options

The visioning stage of the framework was completed by developing a set of robust recommendations to address the key strategic issues identified in Table 7. The SDFP team engaged in a series of individual brainstorming and team discussion activities to finalize the series of responsive strategic options and actions for each issue, relying heavily on the results of the August 2022 SME workshop as the primary input to, and foundation for, the resulting response plan. Table 8 presents the final list of key issue themes and their proposed responses, accompanied by actionable planning objectives and a series of proposed first steps to achieve those objectives. Because there is variability in the amount of human and financial capital needed to undertake these actions, there is no specific timeframe tied to the proposed objectives or the first steps. We recommend the actions be tailored, prioritized, and pursued as part of efforts to plan for the future according to organizational needs and resource availability.

The final list of recommendations includes options and actions to address the key issues from Table 7 related to access to OSH data, the individualization of OSH, and OSH communication approaches (mechanisms and content). There are no options or actions related to research support because it became clear through the option-generating process that significant efforts to address this issue are already embedded in

TABLE 7 Key strategic issues underlying the scenarios, organized by consequence severity if the issue is left unaddressed and degree of known current activity to address the issue.

Key strategic issue	Severity if left unaddressed	Degree of activity	Core topic
IT modernization mandates threaten the pace of scientific productivity and dissemination.	High	Very little	Data access
Employees manage their own safety, health, and well-being.	High	Very little	Individualized OSH
Mis- and dis-information challenge OSH ability to protect and promote the safety, health, and well-being of the workforce.	High	Some	Communication
OSH now has three unique audiences with unique communication wants and needs: industries, employers, and individuals.	High	Some	Communication
Comprehensively evaluating OSH research and practice and effectively allocating resources requires new frameworks to achieve impact.	High	Some	Research support

Abbreviation: OSH, occupational safety and health.

TABLE 8 Robust strategic response.

Key issue theme	Proposed response	Proposed strategic objectives	Proposed first steps
Data access	Develop effective communication and partnerships between IT and researchers.	• Establish fundamental data security concepts as core competencies for OSH researchers and practitioners. • Provide educational opportunities for OSH to maintain awareness of critical information technology and data security issues. • Establish IT data governance policies and approach that support OSH goals. • Incorporate fundamental data security elements into core OSH curriculum.	• Create effective partnerships to develop and disseminate information and training resources for researchers and practitioners. • Review current IT data governance policies and approaches for efficacy and responsiveness in support of OSH. • Incorporate awareness of critical information technology and data security issues into OSH training.
Individualized OSH	Bring OSH to individuals through efficient and effective research and communications.	• Prioritize investment in research and service activities that include a focus on the individual worker. • Develop more individual-level communication and guidance products for a variety of OSH issues and topics, utilizing appropriate supporting technologies to ensure effective and efficient communication strategies. • Identify an approach that allows for quicker development and dissemination of actionable information and guidance for individual workers.	• Ensure priority evaluation criteria (e.g., NIOSH Burden, Need, and Impact[77]; New South Wales Ministry of Health priority setting guide[78]; CHNRI, James Lind Alliance Method, and Combined Matrix Approach[79]) are inclusive of individual-level OSH efforts. • Identify opportunities to simplify and expedite publication requirements and processes for research and communication activities. • Consider just-in-time funding opportunities for research that explores individual worker behaviors, motivations, and decision-making processes. • Establish Boards of Workers to advise on what information and products will be most useful.
Communication approaches	Build the brand and navigate the networks to thwart mis- and dis-information.	• Maintain brand integrity while increasing visibility of OSH organizations. • Develop partnerships to proactively identify and combat mis- and dis-information. • Explore potential mis- and dis-information future scenarios to inform action.	• Enhance capacity and expertise in navigating the information space to reach employers and individual workers. • Resource efforts to proactively address key issues associated with future mis- and dis-information scenarios. • Prioritize the development of information products with broad reach and measurable impact across a variety of audiences.

Abbreviation: NIOSH, National Institute for Occupational Safety and Health.

other activities underway across the OSH community. Examples include the NIOSH Evaluation Capacity-Building Plan, the US Occupational Safety and Health Administration training grant programs, and the Design for Occupational Safety and Health Initiative in the United Kingdom.[80–82] Though we applied a US lens for worker-related safety, health, and well-being when generating the options and actions in Table 8, the proposed objectives and first steps are not specific to a US audience. They may serve as a useful input for OSH organizations in other parts of the world as they also engage in strategic planning and preparedness for future disruptions.

4.2 | Limitations

Because NIOSH is a US federal agency, this inquiry necessarily focused on disruptive changes that impact work in the United States. Before beginning this project, the SDFP team found no evidence that the 2 × 2 matrix method had ever been applied to develop OSH-focused scenarios. Therefore, this application of the methodology was considered a pilot exploration into the utility of the method for designing OSH futures. This, in conjunction with the inherent focus on NIOSH as the primary end-user of the project results, led the SDFP team to limit expert input to NIOSH senior scientists and leaders. These specific project parameters should be recognized when interpreting the SDFP results, as they may have resulted in "blind spots" to perspectives held by others outside the organization. It is possible inclusion of such external points of view could have further enhanced the four scenario narratives and the subsequent identification of relevant issues and potential response options for the broader OSH community to consider when preparing for potential disruptions in the future.[66]

To help fill these potential gaps, the SDFP team made a concerted effort to include both domestic and international events

and resources during the Stage 1 and Stage 2 information gathering exercises, particularly in the development of the current assessment and the scan for signals of potential change across the domain subtopics of work arrangements, employment patterns, work-related risks and hazards, workforce availability, workplace regulation, and STEEP influences. Therefore, though the SDFP was designed primary to inform NIOSH future plans, the results of the project may have value beyond NIOSH and the US OSH community. The explorative external scenarios produced by the SDFP, for example, seek to broadly describe what could happen as external factors develop over time.[83] Because of this, the narratives depict four different future contexts in which NIOSH—and, by default, other OSH organizations—could exist. Therefore, other OSH researchers and practitioners may find value in working from the SDFP scenarios to conceptualize key issues and responsive actions that may be most relevant to their own organizational and cultural contexts. The insights gained from this type of extrapolation exercise can serve as a useful forward-facing complementary input to surveillance data, progress and trend reports, key performance indicators, and additional backwards-to-the-future (i.e., traditional) data for strategic planning purposes. Leveraging both "look back" and "look forward" evidence can enhance the development of robust and innovative strategic plans that can effectively guide the future of organizational actions and decision-making during times of calm progress and periods of volatile uncertainty.[84]

5 | CONCLUSIONS

When interpreting the findings of the SDFP, it is important to remember this study was not a traditional OSH investigation. As is true with other qualitative approaches to inquiry, a strategic foresight project is not designed or intended to have measurable reliability and validity, generalizable findings, or an entirely replicable research design.[85] Furthermore, the strategic foresight community does not profess the practice of foresight to constitute a fully empirical research methodology. Instead, strategic foresight is a structured and evidence-driven practice that can complement more traditional approaches to scientific investigation. For OSH, strategic foresight broadens our toolbox beyond the prevailing quantitative-driven methodological paradigms. It encourages us to envision possible futures based on the evidence we have today, to consider the implications of those futures, to assess our current levels of preparedness to respond should they come to pass in part or in whole, and to devise strategies for what to begin doing now so we are best positioned to thrive in the face of the uncertain future.[18]

The SDFP implemented the practice of strategic foresight to explore how sudden disruptions might impact work and jobs and shape the future practice of OSH and demonstrated the utility of the 2 × 2 matrix scenario planning method within an OSH context. Rather than presupposing what the future *will* be, SDFP searched a variety of information sources and conducted interviews with SME to ascertain what the future *could* be. This information elucidated uncertainties that will influence the future in yet-to-be-determined directions. These evidence-based questions became the building blocks for constructing the stories of four possible futures where disruptions have occurred and impacted work, working people, and the OSH response. Analysis of the scenarios identified several issues that may impede the future efficacy of OSH research, policy, and practice. These issues coalesced around the challenges of data access, individualized OSH, and communication, suggesting these topics are important to consider as strategies are devised to better prepare the OSH workforce to anticipate and respond to future disruptions.

The methods employed for scanning sources of information, interviewing experts, synthesizing data, constructing scenarios, articulating key issues, and generating strategic response options in SDFP can serve as a general blueprint for designing and implementing a strategic foresight project in any subject area. SDFP also demonstrates how to meaningfully apply the Foresight Framework for OSH (Figure 1). This flexible, yet structured, approach can be used to explore the future for a variety of national and international topics that are relevant to protecting and promoting the safety, health, and well-being of workers. As a starting point, NIOSH recently provided examples of ways the framework might be applied to advance other existing OSH research initiatives and programs, including the internationally-recognized NIOSH Future of Work Initiative and Total Worker Health® Program.[26]

Completion of the SDFP satisfied the first four stages of framing, scanning, futuring, and visioning from the Foresight Framework for OSH (Figure 1). Though our primary "client" for this activity was a US federal agency, the findings from our work in these first four framework stages may serve as useful inputs to strategic futures planning at OSH research, policy, and practice organizations across the US and around the world. In addition, the successful completion of the remaining framework stages of *designing* and *monitoring* (Figure 1, Stages 5 and 6) will require support and participation from the broader national and international OSH communities. The robust options offered in Table 8 may serve as useful inputs as OSH research, policy, practice, and training organizations develop, implement, and evaluate short- and long-term strategic plans. In addition, creating regular opportunities for OSH researchers and practitioners worldwide to monitor and communicate about early signals of change can help institutionalize a proactive and forward-facing orientation for OSH. The commitment of time and resources to today's foresight activities can expand and enhance the efficacy of domestic and international efforts to think about and prepare for the future. This investment will better ensure the OSH workforce is strategically positioned to protect the safety, health, and well-being of workers throughout the next major disruption…no matter when, where, or how it occurs.

AUTHOR CONTRIBUTIONS

Sarah A. Felknor and Jessica M. K. Streit conceptualized the Sudden Disruptions Foresight Project (SDFP). Jessica M. K. Streit wrote the initial manuscript. Jessica M. K. Streit and Sarah A. Felknor provided substantial revisions and edits. Nicole T. Edwards provided data

management and input into manuscript revisions, and David L. Caruso provided input into manuscript revisions. John Howard provided input into SDFP conceptualization and manuscript revisions. All authors have provided final approval of the version to be published and agree to be accountable for all aspects of the work and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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The authors declare that there are no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

DATA AVAILABILITY STATEMENT

Research data are not shared.

ETHICS APPROVAL AND INFORMED CONSENT

All work was performed at the US National Institute for Occupational Safety and Health. The activities of SDFP were determined by the NIOSH Human Research Protections Office to constitute non-research public health surveillance under 45 CFR 46.102(1)(2).

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, or other affiliated organizations of the authors.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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