



NATIONAL OCCUPATIONAL RESEARCH AGENDA (NORA)

**NATIONAL OCCUPATIONAL RESEARCH AGENDA FOR TRANSPORTATION,
WAREHOUSING AND UTILITIES**

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Developed by the NORA Transportation, Warehousing and Utilities Council

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INTRODUCTION

What is the National Occupational Research Agenda?

The National Occupational Research Agenda (NORA) is a partnership program to stimulate innovative research and workplace interventions. In combination with other initiatives, the products of this program are expected to reduce the occurrence of injuries and illnesses at work. Unveiled in 1996, NORA has become a research framework for the Nation and National Institute for Occupational Safety and Health (NIOSH). Diverse parties collaborate to identify the most critical issues in workplace safety and health and develop research objectives for addressing those needs.

NORA enters its third decade in 2016 with an enhanced structure. The ten sectors formed for the second decade continue to prioritize occupational safety and health research by major areas of the U.S. economy. In addition, there are seven cross-sectors organized according to the major health and safety issues affecting the U.S. working population. While NIOSH is serving as the steward to move this effort forward, it is truly a national effort. NORA is carried out through multi-stakeholder councils, which are developing and implementing research agendas for the occupational safety and health community over the decade (2016-2026). Councils address objectives through information exchange, partnership building, and enhanced dissemination and implementation of evidence-based solutions.

NORA groups industries into ten sectors using North American Industry Classification System (NAICS) codes. The Transportation, Warehousing and Utilities (TWU) sector encompasses three NAICS code groupings (48, 49, and 22) and is comprised of eight industries. The Transportation sector (NAICS 48) includes all modes of transporting passengers and cargo by air, rail, water, road, and pipeline. The Warehousing sector (NAICS 49) consists of establishments engaged primarily in the storage of goods. The Utilities sector (NAICS 22) covers electric power, natural gas, alternative sources, water, sewage, and other systems.

What are NORA councils?

Participation in NORA councils is broad, including stakeholders from universities, large and small businesses, professional societies, government agencies, and worker organizations. Councils are co-chaired by one NIOSH representative and another member from outside NIOSH.

Statement of Purpose

NORA councils are a national venue for individuals and organizations with common interests in occupational safety and health topics to come together. Councils started the third decade by identifying broad occupational safety and health research objectives for the nation. These research objectives will build from advances in knowledge in the last decade, address emerging issues, and be based on council member and public input. Councils will spend the remainder of the decade working together to address the agenda through information exchange, collaboration, and enhanced dissemination and implementation of solutions that work.

Although NIOSH is the steward of NORA, it is just one of many partners that make NORA possible. Councils are a way to maximize resources toward improved occupational safety and health nationwide, not an opportunity to give consensus advice to NIOSH. Councils are platforms that help build close partnerships among members and broader collaborations between councils and other organizations. The resulting information exchange and leveraging efforts promote widespread adoption of improved workplace practices based on research results.

Councils are diverse and dynamic and are open to anyone with an interest in occupational safety and health. Members benefit by hearing about cutting-edge research findings, learning about evidence-based ways to

improve safety and health efforts in their organization, and forming new partnerships. In turn, members share their knowledge and experiences with others and reciprocate partnerships.

Transportation, Warehousing and Utilities Sector Council

A NORA Transportation, Warehousing and Utilities (TWU) Sector Council was formed during the second decade of NORA. The Council developed a detailed research agenda for that decade, formed subsector workgroups (e.g., trucking, aviation), held meetings of subsectors and the full Council, and tracked research and products influenced by the research agenda. Council leadership documented 69 research projects funded by NIOSH that were responsive to the agenda and more than 300 products developed by NIOSH and/or Council members, including peer-reviewed journal articles, NIOSH publications and fact sheets, and reports and conference proceedings.

The Council was refreshed in September through December 2016. Members who had participated during the second NORA decade were invited to continue, and most did. Invitations to join the Council were also issued to some organizations to ensure broad representation across the different TWU subsectors and to individuals who had shown interest in the work of the Council. The Council currently comprises 48 members and includes representation from federal and state governmental agencies, academia, industry, labor, trade associations, professional and not-for-profit organizations, and experts/consultants. A list of the current Council members is included as Appendix A.

At its first meeting in this NORA decade, the Council discussed its vision for the coming years. The Council seeks to:

- Increase awareness about important safety and health concerns for workers in the TWU Sector.
- Foster research to fill gaps in knowledge.
- Translate research into practice.
- Provide a broad range of stakeholders, including employers and labor, with knowledge and tools they can use so that TWU workers can do their jobs safely and live healthy and productive lives.

What does the National Occupational Research Agenda for Transportation, Warehousing and Utilities represent?

The National Occupational Research Agenda for TWU is intended to identify research, information, and actions most urgently needed to prevent occupational injuries and illnesses in the TWU sector. This National Occupational Research Agenda for Transportation, Warehousing and Utilities provides a vehicle for stakeholders to describe the most relevant issues, gaps, and safety and health needs for the sector. Each NORA research agenda is meant to guide or promote high priority research efforts on a national level, conducted by various entities, including government, higher education, and the private sector.

Because the Agenda is intended to guide national occupational health and safety efforts for the TWU Sector, it cannot at the same time be an *inventory* of all issues worthy of attention. The omission of a topic does not mean that topic was viewed as unimportant. Those who developed this Agenda did, however, believe that the number of topics should be small enough so that resources could be focused on a manageable set of objectives, thereby increasing the likelihood of real impact in the workplace.

NIOSH will use the Agendas created by the sector and cross-sector NORA Councils to develop a NIOSH Strategic Plan. Programs will use burden, need, and impact criteria (BNI) to write research goals that articulate and operationalize the components of the NORA Sector and Cross-Sector Agendas that NIOSH will take up. NORA Agendas and the NIOSH Strategic Plan are to be separate but linked.

Who are the target audiences?

The National Occupational Research Agenda for TWU will help stakeholders and partners to prioritize their work among the many safety and health issues of interest. Stakeholders and partners include persons, groups, or organizations that have a direct or indirect stake in occupational safety and health in the TWU sector. Stakeholders and partners can affect or be effected by the priorities established and are essential for implementing the TWU Agenda. The National Occupational Research Agenda for TWU is intended to inspire decision makers and program planners to include these topics in their top priorities and to guide researchers to relevant topic areas for research proposals. Finally, it is intended to encourage dialogue and collaborating among stakeholders on a subset of key issues.

Target participants in the TWU Agenda are both International and U.S. Domestic and include:

- Research funding sources: governmental agencies, research foundations, and industry-supported research organizations.
- Public and private researchers: government researchers, academic researchers, industry, and foundation-based researchers.
- Industry: employers, trade associations, vehicle and equipment manufacturers, and distributors.
- Labor organizations and unions.
- Regulatory agencies: federal, state, tribal, and local levels.
- Public health agencies: international, federal, state, tribal, and local levels.
- Non-profit and non-government organizations.
- Safety and health practitioners in public and private sectors: individual safety, industrial hygiene, and engineering practitioners; health educators and health promotion coordinators.
- Consensus standards groups.
- Professional associations.
- Other professionals with safety and health interests: e.g., economists, occupational physicians, ergonomists, occupational and physical therapists, and occupational health nurses.

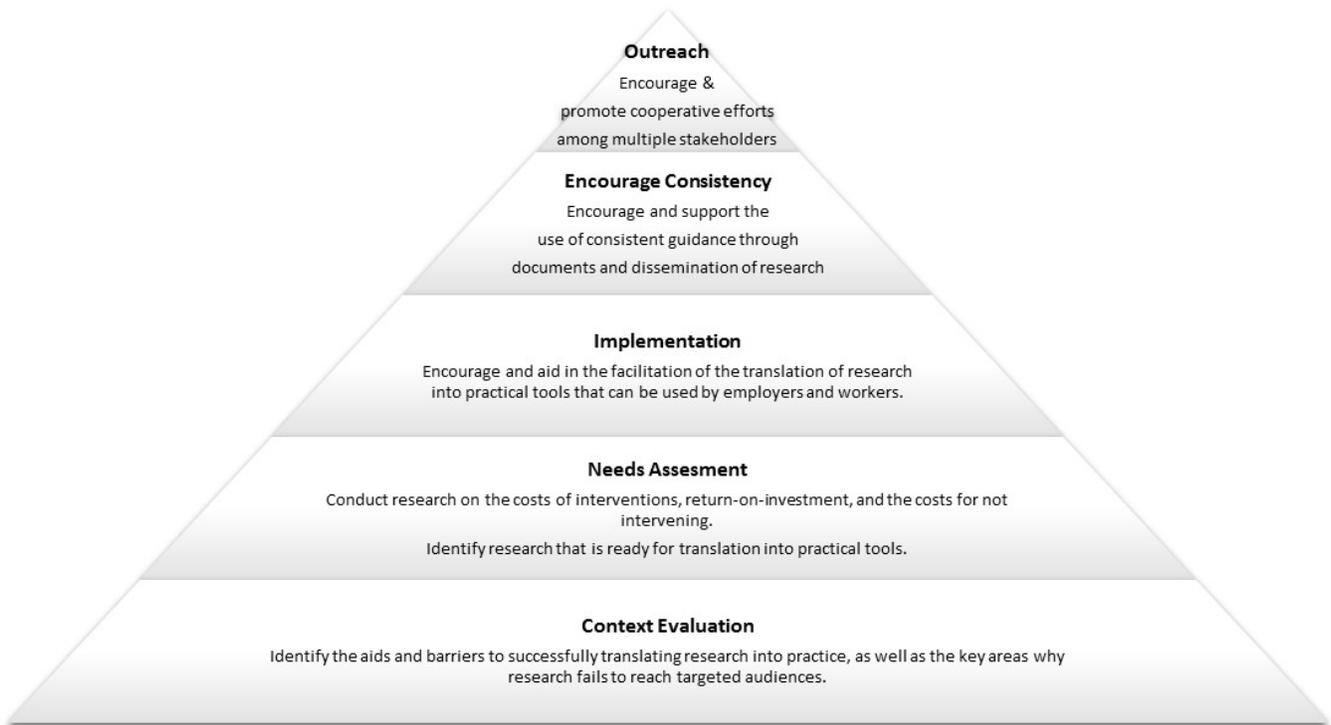
How was the research agenda developed?

The TWU Council began to develop the National Occupational Research Agenda for TWU during a series of virtual meetings held in December 2016, February 2017, and May 2017. Meetings included presentations on the purpose of NORA and its evolution over the first two decades and progress on NORA TWU goals from the previous decade. The first task for the newly formed TWU Council was to develop an agenda for the third decade of NORA. This agenda was to be based on the state of the science, partner and stakeholder needs, and other relevant inputs.

Council members posited ideas for “strategic objectives” that were intended as broad research objectives for the nation and would capture key improvements in occupational safety and health to be achieved. These built on advances in knowledge gained in the last decade, addressed emerging issues, and were expected to be reasonably achievable within the next decade. Council members’ ideas were synthesized into ten overarching strategic objectives for the TWU sector. There were some overlapping concepts in these objectives, but each was considered important and distinct enough to warrant its own objective. Objectives focused on work-related fatalities, illnesses, and injuries among TWU workers, TWU worker health and well-being, TWU worker exposures and control, emerging technologies, work organization, economic and demographic worker trends in the TWU sector, and approaches for translation of research into practice. The common themes among the strategic objectives, including fatigue, slips and fall injuries, and new technology, were intentionally left dispersed throughout the strategic objectives and emphasize the complex nature of issues for the TWU sector. Volunteer workgroups wrote descriptions for each objective, which were reviewed by the Council. These descriptions included citations of available data and research demonstrating the need for each strategic objective and drew

upon member’s expertise that progress on each objective would be expected to make a difference in the safety and health of TWU workers. (A list of workgroup members is included as Appendix B.) These objectives form the basis for this agenda.

An overall concern for TWU Council members, expressed in initial meetings, was translation of research findings into practice for the larger TWU community. A model depicting stages and types of activities needed to achieve this was developed. The model depicted below provides a framework for conceptualization and development of the ten TWU strategic objectives from recognition of needs, aids, and barriers (context evaluation) to outreach and dissemination of products to stakeholders:



After review and input from the Council, public comment on the draft agenda will be sought through a public docket identified in the *Federal Register*. Public comments will be received and the agenda revised accordingly.

THE OBJECTIVES

Objective 1: Reduce deaths and injuries among TWU workers

Approximately 8 million workers are employed in the Transportation, Warehousing and Utilities industrial sector. Of them, approximately 6.7 million work in the transportation and warehousing industries and 1.3 million in utilities [BLS 2017a]. In 2015, there were 838 occupational fatalities in the Transportation, Warehousing and Utilities Sector; 546 of the deaths occurred in the truck transportation, 77 in support activities for transportation, 64 in transit and ground passenger transportation, 39 in utilities, 29 in couriers and messengers, 23 in air transportation, 19 in the postal service, 13 in water transportation, 11 in warehousing and storage, 11 in rail transportation, and 6 in other subsectors. Of the 799 transportation and warehousing (TW) fatalities, 623 (78%) were employed in the private sector, 142 (18%) were self-employed, and 34 were employed by government agencies at the time of death. Of the 39 utilities fatalities, 21 (54%) were employed in the private sector, and 17 (44%) were employed by government agencies at the time of death [BLS 2017b]. In 2015, 624 (30%) of all transportation incidents occurred in the TWU sector, highest percentage of any industry sector. Transportation-related incidents represent a high proportion of fatalities in all TWU industry sub-sectors, with the greatest burden in the truck transportation sub-sector (454 of 546 or 83%) [BLS 2017c]. Concurrently, the nonfatal transportation and warehousing occupational injury and illness rate was 204.3 injuries and illnesses per 10,000 full-time workers, 118% above the total private industry injury and illness rate of 93.9/10,000 in year 2015 [BLS 2016]. Among the 90,990 nonfatal transportation and warehousing injury and illness cases in private industry in 2015, 31,590 (35%) were in truck transportation, 13,180 (14%) in air transportation, 13,080 (14%) in couriers and messengers, 12,820 (14%) in the warehousing and storage industry, 8,320 (9%) in support service activities for transportation, 7,610 (8%) in transit and ground transportation, and 3,210 (4%) in rail transportation [BLS 2017d].

Addressing the elevated burden of deaths and injuries in the TWU industry requires a multi-faceted public health approach. Comprehensive injury surveillance is needed to identify TWU populations at greatest risk for injuries and deaths. Development and implementation of targeted injury prevention interventions and policies and evaluation of the implemented interventions and policies are needed to provide evidence of effectiveness of TWU interventions and policies, including cost-effectiveness. Effective evidence-based TWU injury prevention policies and interventions can reduce risk of injury, resulting in a reduction of injuries and deaths in the TWU industry.

Research and practice needs specific to truck transportation:

- Increase implementation and evaluation of collision avoidance technologies, such as collision warning, autonomous emergency brake in commercial vehicles, and in-vehicle monitoring technologies (National Transportation Safety Board 2017–2018 most wanted list) [NTSB 2017].
- Evaluate and implement effective interventions into company policies and procedures such as fatigue (physical or mental) management programs, driver training, and coaching programs to prevent distracted driving and increase seatbelt use.
- Conduct research into the impacts of economic pressures, scheduling, and non-standard work arrangements on crashes and injuries.
- Develop and coordinate partnerships to disseminate information on methods to reduce risk factors for work-related injuries associated with fatigue and distracted driving in truck drivers.
- Develop and coordinate partnerships to disseminate information on ergonomic workspace evaluation of the truck cab environment.
- Incorporate effective interventions into employer policies and procedures for activities with the potential for slips, trips, and falls (e.g., work on loading docks, climbing and working on trucks, and getting into and out of trucks).

- Develop and coordinate partnerships to promote positive safety cultures in truck transportation companies through company implementation and enforcement of better worker safety policies and practices.

Research and practice needs in other modes of transportation, warehousing, and utilities:

- Conduct research into the causes and prevention of injuries, including transportation-related injuries; slips, trips, and falls; and struck-by incidents.
- Incorporate effective interventions into employer policies and procedures to prevent injuries, including transportation-related injuries; slips, trips, and falls; and struck-by incidents.
- Develop and coordinate partnerships to assess the contribution of fatigue to work-related injuries and disseminate information on methods to reduce risk factors for fatigue.

Objective 2: Reduce musculoskeletal disorders among TWU workers

Numbers and reported rates of musculoskeletal disorders are high among TWU workers. The transportation and warehousing industry had an incidence rate for work-related musculoskeletal disorders (WMSDs) of 76.4 in private industry and 148.0 in local government per 10,000 full-time employees in 2015, more than two and four times respectively than all U.S. workers (32.2 per 10,000 workers). The utilities industry had an incidence rate for work-related musculoskeletal disorders (WMSDs) of 27.7 in private industry and 96.8 in local government per 10,000 full-time employees in 2015 [[BLS 2016](#)]. Of the 90,990 transportation and warehousing private industry injuries and illnesses resulting in days away from work in 2015, 37% (n=34,010) resulted from overexertion and bodily reaction. Within transportation and warehousing, the air transportation (55%), courier and messenger (50%), and warehousing and storage (48%) sub-sectors experienced higher percentages. Within the utilities sector, 40% of the injuries in private industry resulted from overexertion and bodily reaction [[BLS 2017d](#)]. Musculoskeletal disorders are associated with high costs to employers such as absenteeism, lost productivity, increased health care, disability, and workers' compensation costs [[NRC/IOM 2001](#)].

Musculoskeletal cases result in a higher median number of days off from work to recuperate than the overall average for lost-time injuries or illnesses. National workers' compensation premium rates correspond with injury rates and are a burden to employers (\$1.85 per \$100 of payroll in the year 2014) [[Oregon Department of Consumer & Business Services 2014](#)]. Workers' compensation costs were higher in the trade, transportation, and utilities industry (\$0.54 per hour) than in all service-producing industries (\$0.39 per hour) but lower relative to all goods-producing industries (\$0.80 per hour) [[BLS 2017e](#)]. In 2007, musculoskeletal disorders had a direct cost (medical costs plus indemnity) of \$1.5 billion. The indirect costs (lost wages, fringe benefit losses, home production losses, and training, hiring, and disruption costs) amounted to an additional \$1.1 billion [[Bhattacharya 2014](#)]. Claims for WMSDs represented the highest percentage of claims in the TWU sector between 2002 and 2010 in Washington State (39.9%), for a claim rate of 140.2 claims per 10,000 full-time equivalent (FTE) workers. The median claim cost was \$11,284 and median length 45 days [[Anderson et al. 2013](#)]. The ergonomic claim rate for TWU for Ohio Bureau of Workers Compensation (OHBWC)-insured, private employers, single location was 105 per 10,000 full-time equivalents (FTE) and represented 22.0% of all TWU claims 2007–2011 [[NIOSH 2015b](#)].

Musculoskeletal disorders are associated with manual handling, repetitive and forceful motions, sustained awkward postures, and whole body vibrations. Research should be conducted to evaluate rates and trends in musculoskeletal disorders across disparate and independent tracking systems and compare data across systems. Research should also be conducted to estimate underreporting for all of TWU and within individual sub-sectors. For example, the trucking industry does not appear in the above list of sub-sectors experiencing higher percentages of WMSDs, a possibly counterintuitive result that may be explained by the presence of a dispersed workforce, and greater percentages of independent operators and smaller companies in comparison to some other sub-sectors, such as air transportation. Further intervention and evaluation research should focus on

WMSDs in TWU with special emphasis on high-risk populations like older workers, the courier and messenger sub-sector, warehousing and storage, air transportation, and other sub-sectors in which significant underreporting is observed. Research is needed to identify the most effective interventions and to assess return-on-investments. This includes changes in designs of workplaces and tasks, administrative controls, training, and personal protective equipment. Efforts are needed to translate and disseminate evidence-based prevention strategies and train workers in identification and reporting of hazards that contribute to increased incidence of WMSDs.

Objective 3: Promote and improve the health and well-being of TWU workers

TWU workers are subjected to a number of physical and psychological stresses. The typical work and life experience may include irregular work and sleep hours, physical inactivity, prolonged occupational sitting, poor eating habits and nutrition, erratic work schedules, limited access to health care, social isolation, burnout, job insecurity, and mental and physical stress. These combined circumstances have major implications for the industry, and the results can compromise long-term health [[Birdsey et al. 2015](#); [Sieber et al. 2014](#); [Scovill et al. 2012](#); [Iversen 2012](#)]. Psychological distress was found to be significantly greater in this population compared to the U.S. working population comparison norm [[Orris et al. 1997](#)]. Reports indicate that overweight and obesity rates are considerably higher in this population than those of the general American population. Studies show that up to 65% of TWU workers have body mass indices that qualified them as obese [[Sieber et al. 2014](#); [Orris et al. 1997](#); [Wiegand et al. 2009](#)]. Moreover, the risks of diabetes mellitus (9% vs. 7%), hypertension (32.8% vs. 24%), and obstructive sleep apnea (8% vs. 4%) are well above those for the general population and other occupational cohorts [[Martin et al. 2009](#); [Thiese et al. 2015a](#); [Thiese et al. 2015b](#)]. Shift work and erratic hours increase the risk for sleep deficiency, which is associated with metabolic impairment, chronic disease, and early mortality [[Knutson 2007](#); [Buxton and Marcelli 2010](#); [Wingard and Berkman 1983](#)]. Poor sleep and other health conditions are also associated with increased risk of occupational safety incidents [[Tregear et al. 2009](#); [Burks et al. 2016](#); [Laberge-Nadeau et al. 1996](#)]. Cigarette smoking rates in this population remain significantly elevated compared to working adults in the U.S. (51% vs. 19%) [[Birdsey et al. 2015](#); [Sieber et al. 2014](#)]. Complicating these problems is the fact these workers are a medically underserved and under-studied population with low health care access and use [[Layne et al. 2009](#); [Solomon et al. 2004](#)].

Research is needed to evaluate the impact of specific working conditions and consequent lifestyle implications in a range of health and well-being outcomes, including research evaluating the impacts of altering working conditions. In the surveillance domain, no previous studies have assessed the prevalence of mental disorders among TWU workers, which is essential for developing assessment techniques, educational programs, and mental health services. Data are also lacking on the onset and progression of excess body weight for workers entering particularly obesogenic TWU jobs, which is a critical gap given that obesity may drive excess risk of many other health outcomes. Research is needed on the economic costs of chronic diseases and other health conditions to workers, employers, productivity, and the health care system. There is a need to improve access to health care, screening and treatment for chronic diseases, and other medical conditions, such as cardiovascular disease, diabetes mellitus, hypertension, chronic obstructive pulmonary disease, sleep disorders, and tobacco use disorder. Research is needed on the cost-effectiveness of screening and treatment in terms of impacts on worker well-being, performance of safety-sensitive work, productivity, and long-term health costs. To increase the efficacy and use of workplace (including truck stops) interventions, such as health and wellness programs, research is needed that evaluates their effectiveness, acceptance, and return-on-investment. Efforts are needed to translate and disseminate evidence-based prevention and treatment strategies. Lastly, given job conditions and poor health outcomes, workers in the transportation industries might be at-risk for diminished life expectancy; however, no research has assessed this hypothesis.

Objective 4: Increase knowledge about the association between TWU worker exposures and adverse health outcomes, and effective prevention and control strategies

TWU workers are exposed to a myriad of chemical, physical, and biological occupational exposures that may negatively impact their health. Examples include diesel fumes and particulate in and around ports [[California Air Resources Board 2016](#)], carbon monoxide, silica, noise, electromagnetic radiation, vibration, heat and cold, and common infectious agents such as influenza and norovirus as well as rare and emerging pathogens, such as Ebola and Zika. Forty percent of TWU workers are exposed to vapors, gas, dust, or fumes, and 53% do work outdoors [[NIOSH 2010](#)]. Work schedules may be irregular and often combine limited meal and bathroom access with shifts well in excess of eight hours, putting both employees and the public at risk [[NIOSH 2010](#); [NIOSH 2015a](#); [American Restroom Association 2008](#)]. Regular overtime of more than five hours a week was associated with higher mortality rates for five years following the overtime [[Nylen 2001](#)]. Research is needed to examine associations of these hazards with negative outcomes and compare their rates, severity, and costs with those experienced by other populations.

Some TWU workers have increased risks associated with interacting with the public as part of the job, while others may suffer from the hazards of social isolation. Violence, social stressors, infectious agents, and emerging diseases may result from interactions with the public or other workers. Ten percent of TWU workers perceive their workplace as unsafe; seven percent have been threatened, bullied, or harassed on the job within the past 12 months [[NIOSH 2015a](#)]. Updated methods of protecting workers from these hazards are needed. Improved barriers to assaults or infectious agents, for example, would benefit many TWU job classes. Their efficacy for workers, employers, and the broader public needs assessment.

Research is needed to develop and evaluate the effectiveness of interventions across the hierarchy of controls for the diverse agents to which TWU workers may be exposed. The effectiveness of elimination and substitution of hazards, use of engineering and administrative controls, and effective use of personal protective equipment should be investigated. Efforts are then needed to translate and disseminate the evidence-based strategies to reduce these hazardous exposures and spread understanding of the full range of costs and benefits.

Objective 5: Increase knowledge about the role of worker characteristics and impairment on TWU worker safety, health and well-being, and effective prevention strategies

The TWU workforce varies widely and increasingly in terms of demographics and capabilities. The proportion of older workers in the workforce continues to increase [[Vincent and Velkoff 2010](#)]. In many cases, employers are required to provide accommodations that keep workers with physical and other health limitations on the job [[EEOC 2017](#)]. These changes increase the need for understanding how specific characteristics of TWU workers affect impairment of activity and subsequent risks of injury or illness [[Schulte et al. 2012](#)].

These characteristics include:

- Aging (e.g., reductions in cognitive and physical health of older workers) [[Garg 1991](#); [Gauchard et al. 2003](#); [Popkin et al. 2008](#); [Llaneras et al. 1998](#)]. The percentage of TWU workers aged 55 or more increased from 23.9% in 2011 to 25.7% in 2016 [[BLS 2017f](#)].
- Inexperience (e.g., new or young workers) [[Blom et al. 1987](#)]. The percentage of TWU workers aged 25–54 years decreased from 70.5% in 2011 to 67.0% in 2016, while workers aged 16–24 increased from 5.7% in 2011 to 7.3% in 2016 [[BLS 2017f](#)].
- Communication barriers (e.g., language, literacy or hearing loss).

- Physical limitations (e.g., disabled workers or injured workers returning to work).
- Cognitive impairments (temporary or permanent).

Induced cognitive impairments are a particular concern for employers because of the potential safety impact on the public as well as the workforce. These include fatigue and alertness among transportation drivers, equipment operators, and those responsible for chemical storage or transport and energy sources; distractions (such as use of cell phones and other technologies); inattention (such as from boredom); and impairment from substance use (illicit and licit drugs or alcohol) [[Creaser et al. 2011](#); [Klauer et al. 2014](#); [Popkin 2015](#)]. Addressing the effect that these characteristics can have on TWU workers' safety, health, and efficiency will require an understanding of contributors to impairment, such as work organization (e.g., duty times and rest periods), administrative policies (e.g., attendance and sick leave), physical and cognitive demands of work, medical conditions and treatment, and work-life balance.

There is a further need to evaluate workplace interventions. Systematic approaches currently recommended include workplace policy and practice changes, fatigue management programs, and safety management systems. Additional interventions might include technological assists such as automated sensing devices and alerts that could help TWU workers recognize impairment and robotic aids that provide assistance to avoid injury when impairment goes unnoticed. Improving the safety and health environment for workers with identified needs, including older workers and those with physical limitations, could enhance safety for all workers [[Marshall et al. 2009](#)]. Comprehensive evaluations should further address effectiveness and return on investment.

It is important that the research approaches and interventions proposed to meet this objective not penalize workers for their health status and needs. It should also be recognized that workers with apparently limiting characteristics, even impairments, often possess additional assets; for example, older workers have experience, younger workers may have a new eye to problems, and disabled and injured workers can shed light on the experience of other workers who may be in pain but not yet reporting injury [[Tuominen 2007](#)].

Objective 6: Encourage Prevention through Design

Prevention through Design (PtD) is an effective and durable means to prevent occupational injuries, illnesses, and fatalities. PtD eliminates or reduces hazards by including safe design into all phases of work places, work spaces, tools and equipment, and materials. When coupled with supply-chain and life-cycle assessments, designing-in ergonomic safety and designing-out hazards are effective options for preventing injuries from repetitive strain, acute trauma, and process failure. PtD addresses occupational safety and health needs by eliminating hazards and minimizing risks to workers throughout the places of work, tools, equipment, machinery, substances, and work processes (including their construction, manufacture, use, maintenance, and ultimate disposal or re-use) [[NIOSH 2011](#); [NIOSH 2013](#)]. Studies suggest design as a significant contributor in 37% of work-related fatalities [[Fisher et al. 2008](#)]. Evidence suggests that the successful implementation of prevention through design concepts can greatly improve worker health and safety [[NIOSH 2006](#); [Lin 2008](#); [Schulte et al. 2008](#)].

The TWU sector includes a wide range of supply chain and workplace PtD opportunities. These include working at elevation, working with energized equipment, materials handling, ingress and egress from vehicles, control/operation and seating designs, blind spots on trucks and buses, awkward loading of items in cargo holds and overhead bins of airplanes, and exposures to cold and heat in warehouses and engine rooms. Research is needed to develop promising design solutions to these and related engineering problems [[Sahl and Kelsh 1997a,b](#)]. In addition, the increasing diversity of our workforce creates opportunities to address ergonomic differences due to age, sex, and girth of the modern workforce [[Kelsh and Sahl 1996](#)]. There are opportunities for improvements in work schedule, break and rest periods, and fatigue management within this sector. The significant utilization of contract personnel increases the value of consistent PtD implementation across the supply chain. Case studies have been developed in some industries, highlighting the positive impacts of PtD [[Cervarich](#)

[2008](#); [Kovalchik et al. 2008](#); [Lincoln et al. 2008](#); [NIOSH 2006](#)]. Case studies need to be developed that apply broadly across the TWU sector and also narrowly within specific high-risk occupations [[Kelsh and Sahl 1997](#)].

Objective 7: Proactively address the safety implications of emerging technology

The U.S. economy is moving into a new era where technology, especially automation, is rapidly advancing, introducing more sophisticated robots and vehicles into the workplace. The International Federation of Robotics reports that robot sales increased by 15% in 2015, the greatest single year increase recorded [[IFR 2016](#)]. They further project 12% annual growth through 2019 and that the market will be driven by compact and easy to use collaborative robots, a new type of robot designed to work alongside and in cooperation with human workers. Wearable robotics, such as powered exoskeletons, designed to reduce the physical load on workers, are beginning to appear in the workplace, and their availability is anticipated to grow in the coming years [[Lowe et al. 2016](#)]. Remote controlled and autonomous ground, marine, and aerial vehicles are increasingly being introduced to conduct work that would be difficult and dangerous for workers, and many will work in a shared space with workers. Automated safety features are increasing in motor vehicles, autonomous commercial trucks and transit vehicles are currently being piloted on U.S. roadways, and transportation generally is on the path to both partially and fully automated vehicles. Projections vary on when partially and fully autonomous vehicles will be commonplace, but some project this could be within the next decade [[Kessler 2017](#)]. Examples of current and anticipated applications of robotics and autonomous vehicles in the TWU sector include mobile collaborative robots and automated guided vehicles in warehousing; robotic exoskeletons and prostheses across TWU industries; drones in warehouses and utilities; partially and fully autonomous commercial trucks, transit vehicles, ships, and boats; commercial trucks using connected vehicle technologies; and positive train control systems.

These technological advancements have the potential to increase worker safety through expanded use of robots for work that is dangerous for humans, the use of robotic systems to augment worker abilities, and the use of automated technologies to reduce opportunities for operator error. Such advancements may contribute to reductions in the large numbers of deaths, injuries, and musculoskeletal disorders highlighted in Objectives 1 and 2. However, there are also concerns that robots and automated technologies could contribute to worker injuries and stress, as well as job loss. The traditional paradigm of keeping workers away from operating robots will not apply to many of these new types of robots. Safety guidance and standards will need to be developed and refined, including addressing circumstances in which existing standards may be incompatible with technologic advancements. Interactions between humans and machines are complex, and it is important to study and address the human machine interface [[Flemisch et al. 2011](#); [Murashov et al. 2016](#)]. While automated systems are designed to reduce the burden on operators and minimize operator error, there can be unintended consequences that negatively impact worker safety [[Volpe 2012](#)]. This includes automation contributing to reduced attention and worker fatigue [[Schömig et al. 2015](#); [Vogelpohl 2017](#)]. Rapid advances in technologies increase the potential for unforeseen hazards for workers and demands the attention of occupational safety and health stakeholders. Potential displacement of workers associated with robots and automation taking over some jobs, and creating new jobs with new skill requirements [[Acemoglu & Restrepo 2017](#); [National Academies of Science 2017](#)], has the potential to impact worker psychosocial well-being. Research and practice needs include:

- Surveillance to assess trends in worker exposures and associated injuries
- Risk factor identification, including study of impacts of automation on cognitive function
- Study and design of the human machine interface; study of interactions between humans, robots, and automation
- Study of worker psychosocial impacts associated with changes in how work is done
- Development and evaluation of interventions

- Context evaluation
- Needs assessment
- Implementation
- Standards and policy development, with attention to encouraging consistency
- Health communication and dissemination
- Outreach

Objective 8: Support safe workplaces through organizational-level factors, programs and measures

The workgroup for this strategic objective identified several sub-objectives.

8.1 Research is needed on the impact of the organization of work on TWU worker health and well-being. Examples include work scheduling systems, training, and job stress.

Over the past couple of decades, researchers who focus on worker health and well-being have converged from multiple disciplines, including occupational health and safety, occupational health psychology, industrial hygiene, occupational medicine, epidemiology, etc. The result of these synergistic interactions is a renewed focus on the factors that influence worker health for better or for worse. NIOSH has identified Total Worker Health[®] as an important concept that implies a shift in focus in two important ways: 1) to consider the features and conditions of work that improve health rather than solely focusing on those that harm health; and 2) to take a more holistic view of worker health as a product of work and home life experiences [[NIOSH 2017](#)]. For example, research has demonstrated the importance of work scheduling system design, because the failure to incorporate schedule considerations that enable workers to obtain sufficient rest and recovery has the potential to influence fatigue, alertness, performance, and thus safety outcomes [[Åkerstedt & Wright 2009](#); [Beus et. al. 2010](#); [Clarke 2006](#)]. However, additional research is needed specifically for the TWU worker population and regarding the long-term implications of shiftwork and overtime for health and well-being. Other such important topics include areas of job stress, trauma, and training for behavioral change to prevent or mitigate risks to health and safety.

8.2: Research is needed to identify and evaluate methods of reducing risk and for improving health and safety outcomes for the substantial numbers of TWU workers who work independently or remotely.

Special attention is needed for the population of TWU workers who are alone in the field. For example, vehicle drivers, utilities workers, and workers in marine transport may work either independently or in unsupervised work teams. Research areas may include emergency first-aid, increased response time, forces of nature (weather, animals, etc.), and survival mechanisms. For distributed work teams and lone workers, research is needed to identify the role and impact of important organizational and job-level factors such as work contextual features (e.g., workload, control), psychosocial characteristics (e.g., supervisor support), and safety culture. Furthermore, it is also necessary to evaluate the utility and unanticipated consequences of current and future technological advancements aimed at monitoring distributed workers and work teams. This may include remote tracking (video, 2-way radio, cell phone, vehicle-tracking devices, etc.) and remote interventions (automated, mechanical devices).

8.3: Research is needed to identify context appropriate, methodologically rigorous processes to assess, intervene, and monitor changes in the safety and health cultures of TWU workplaces.

The assessment of safety and health culture in organizations has been studied and demonstrated as important for health and safety outcomes [[Short 2007](#)]. However, additional research is needed for the TWU organizations specifically, to develop assessment methods that not only adhere to scientific standards, but include considerations for continuous improvement, sustainability, and account for the myriad of difference across

organizations that might influence the success of interventions. The result of this research could include outputs such as assessment models, intervention guidelines, evaluation frameworks, and guidance documents for conducting evaluations with high fidelity.

8.4: Research is needed to identify the most effective strategies and methods for protecting workers within an organization such as safety management systems, to identify appropriate methods of organizational integration, and also to address return on investment for TWU stakeholders.

Activities that support this objective may include research into risk assessment strategies, safety policies and promotion activities, the organization of work, work scheduling systems, ensuring safe vehicles and equipment, and administrative controls, as well as education and training. Research is also needed to identify methods for estimating investment in those activities, how to measure returns, and what is necessary to demonstrate a sufficient, positive return. Outputs from this type of research could include off-the-shelf safety management systems, as well as other recommendations to identify what researchers can do and how they can communicate return on investment to TWU organizations.

Objective 9: Increase understanding of how changes in the economy affect the safety and well-being of TWU workers

The changing nature of work in the U.S. revolves largely around the fissuring of the workplace and the use of non-standard work arrangements. These non-standard or alternative work arrangements include temporary workers from agencies who supplement an organization's employee rolls on a non-permanent or intermittent basis, independent contractors who provide services to a business but are not part of the employment rolls, and gig work, often referred to as "app-based" work because of the use of technology connecting workers to customers. Non-standard work arrangements include day laborers, temporary, seasonal, on-call workers, independent contractors, and freelancers. The growth in alternative work arrangements may be due to a variety of factors: demographic shifts; workers' desire for flexible work hours and work/life balance; their need to replace a more traditional job that was lost during the last recession; technological changes that have enhanced worker monitoring; tracking of worker reputations; work standardization, mobility, and telework; increased managerial efforts to focus on providing stability and support only to core employees; and competitive pressures to contract out for standardized and lower-wage work [[Katz and Krueger 2016](#)].

These general trends in work arrangements are reflected in the transportation and warehousing sectors. The probability of a transportation and warehouse worker being in a non-standard work arrangement was 10.8% in 2005, based on the Current Population Survey Contingent Work Supplement, but rose to 17.5% in 2015 based on a RAND survey designed to replicate the Contingent Work Supplement [[BLS 2005](#); [Katz and Krueger 2016](#)]. The steepest increase in alternative work arrangements was in workers 55 to 75 years old, making older workers of particular concern in these work arrangements [[Katz and Krueger 2016](#)]. In addition, a [Pew Research survey \[2016\]](#) found that one in four online platform 'gig' workers worked with a ride-hailing service such as Uber or Lyft. This group represents 2% of U.S. adults (and thus a greater percentage of employed adults).

Available information on injuries and illnesses among temporary worker populations is inconsistent, but over the past 20 years, some studies have shown increased occupational safety risks [[Benavides et al., 2006](#); [Smith et. al. 2010](#)]. While data indicates that temp agency employees are a relatively low share of transportation and warehousing employment [[Katz and Krueger 2016](#)], the Smith et. al. [2010] study of Washington State workers' comp claims filed by temporary help agency employees found that 30% of indemnity claims (claims that resulted in indemnity payment for lost work time) were in the transportation and warehousing sector.

The transportation sector also shares the problem of employees misclassified as independent contractors, and thus losing employee protections, including workers' compensation, unemployment insurance, and the right to self-organization (typically union representation) and collective bargaining [Belzar and Sedo 2017]. In trucking, workers are increasingly not hired as employees and instead entering lease-purchase arrangements with carriers as contractors, binding them to their employer with debt they cannot sustain [Viscelli 2016].

Competitive pressures, new technology, and alternative work arrangements appear to be leading to the adoption of work schedules that may be detrimental to safety, health and well-being. [McMenamin \[2007\]](#) indicates that transportation and warehousing has among the highest prevalence of workers with "alternate shifts" (shifts falling at least partially outside the day shift range of 6AM to 6PM). Overall U.S. prevalence is 17.7%, but prevalence in transportation and warehousing is 31.5% [[McMenamin 2007](#)]. Scheduling algorithms and the use of brokering apps might be making the problem worse. Transportation and warehousing has a much higher prevalence of on-call workers (11.3% in 2015) than any other sector [[BLS 2017a](#); [Katz & Krueger 2016](#)]. Rail, maritime, air, and passenger transit sub-sectors all have workers whose time on-call is not well tracked and who may also have long commutes or second jobs. We need a complete picture of time at work in order to determine impacts on sleep, fatigue, and injury.

As the prevalence of non-traditional work arrangements increases, so does the need to investigate, analyze, and evaluate practices that affect the safety and health risks of these workers in these arrangements. This could include research to explore economically driven risks such as increased competition leading to fatigue, burnout, and risks for injury; increased use of app technology; inadequate resources for small businesses and the self-employed; employer costs associated with training temporary workers; and the decline of unionization and its effects. Research is also needed to determine and analyze failures to address risk (lack of knowledge about how/where to report injuries or workers' rights; worker failure to recognize or raise concerns about safety and health risks; concerns about reprisal, dismissal, and future employment; language or cultural barriers; confusion as to the responsible party for training; and employer's reluctance to record injuries or illness of temporary workers). There is so far, little health and safety research on how non-standard work arrangements are affecting the safety and health of workers, including transportation and warehousing workers. To build the research, there is a need to establish standard meanings for terms such as temporary, on-call, shift work, etc., so that study results can be understood and compared and to more precisely describe and track work arrangements in transportation and warehousing.

Objective 10: Foster translation of research into practice to improve the health and well-being of TWU workers

There is often a gap between research and practice in many safety and health areas for TWU workers. "Discrepancies between evidence-based, efficacious interventions and what actually occurs in practice are frequently so large as to be labeled a "chasm" [[Glasgow & Emmons 2007](#)]. Using the Research to Practice framework aids in achieving desired outcomes through collaboration with partners to address priority needs that have the highest potential for successful implementation. This approach also helps in providing a stronger return on investment [[Brownson et.al 2012](#)]. Research is needed for the improvement of the safety, health, and well-being of all TWU workers, and the research must be translated into information products and interventions that are appropriate and effective for TWU workers.

In an effort to bridge the chasm, both barriers and aids of research into practice must be identified. Returns on investments and costs of not intervening must be determined to make a strong business case for conducting research and disseminating results that can support and facilitate the adoption of effective and efficient safety and health practices. These practices include addressing exposures to and protective measures for a broad spectrum of safety and health hazards.

The workgroup for this strategic objective identified several sub-objectives.

10.1 Identify the aids and barriers to successfully translate research into practice, as well as the consistently cited reasons why research in key areas fails to reach targeted audiences.

The public, funders and oversight agencies expect research to produce tangible outcomes; ideally, outcomes that mitigate TWU worker problems and go above-and-beyond building the body of knowledge in the field. However, research is not always translated into practice, nor does it always reach the intended audience.

To address this issue, researchers must conduct structured evaluation activities to identify (a) the aids and barriers of translating research to practice and (b) the reasons behind the failure of research to reach the intended audience. These activities include data collection and analysis, as well as TWU stakeholder engagement. The result of these activities will enable researchers to develop strategies and tactics tailored to TWU audiences to improve the translation of research findings into products, guidance and tools that can directly influence TWU worker well-being.

10.2 Demonstrate both the cost benefit of intervention and the return on investment (ROI) for identifying hazards and mitigating risk.

Management may fail to realize the benefits and returns on engaging in appropriate risk management techniques to help maintain the health and safety of TWU workers. Proactive and predictive engagement activities can provide insight in terms of changes needed in the management system and eventually result in a safer and healthier workplace and substantially reduced costs.

Topics of interest include: exploring corporate levels of commitment and engagement in safety management systems; comparing and determining cost benefits of engaging in practices related to safety management systems of different origins; designing tools to evaluate effectiveness and efficiency of safety management system implementation in companies; and, assessment of similarities, and differences between safety management systems encouraged and required by different groups, and assessing how such programs might be integrated.

10.3 Encourage the translation of research into practical tools that can be used by employers and workers.

Organizations typically operate by utilizing practical tools that are not only accessible and flexible, but also easy to understand and implement. Examples of these tools include assessment tools that cover health and safety exposure, such as noise, vibration, radiation, sleep work ratio, chemical exposure, etc. However, the term "tools" can also refer to any tangible product that aids the organization in accomplishing their safety objectives. Therefore, policy/procedure improvements, data surveillance, root-cause analysis, and communication/education mechanisms are other possible examples.

However, those tools cannot be built if research-based guidance is not translated sufficiently. Researchers can aid in this effort, but it is necessary to first identify products or topics that are viable candidates for translating research to practice. Criteria may include easiest to develop, greatest area of need, and highest potential for successful implementation. Once identified, the next step is to encourage the translation of research into practical tools that can be used by employers and workers. Organizations will then be able to access and utilize those tools to improve safety management system elements, improving overall health and safety outcomes for TWU workers.

10.4 Encourage and promote cooperative efforts among multiple stakeholders to ensure precise and relevant safety and health guidance for all segments of TWU workers.

Currently, many federal regulatory agencies and standard setting organizations utilize various approaches in an attempt to implement effective safety and health programs. Although these safety management programs may

share similar characteristics, they are all different. For example, some agencies require implementation of a safety management system (SMS) for subsets of their employees or operations, leaving many employees and work tasks outside coverage of the SMS, while others encompass all employees. Companies attempting to conform to individual standards may find conflicting guidance and different approaches. Research needs to be done to compare the required behaviors and protective measures each approach takes. There also needs to be comparative studies to determine the effectiveness of each approach and how best practices can be incorporated into all approaches designed to improve the health and well-being of TWU workers. The current approaches should also be studied to determine the conflicts faced by organizations that may deal with various requirements to meet the individual needs of their stakeholders including both government and private organizations.

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APPENDIX A: MEMBERS OF THE TRANSPORTATION, WAREHOUSING AND UTILITIES (TWU) SECTOR COUNCIL

Co-Chairs

Dawn Castillo	NIOSH
Eric Wood	University of Utah

Members

Mary M. Bauer	OSHA
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Michael H. Belzer	Wayne State University
Terry Bunn	University of Kentucky
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Guang-X. Chen	NIOSH
Elizabeth Dalsey	NIOSH
Enjoli DeGrasse	International Brotherhood of Teamsters
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David Goettee	Federal Motor Carrier Safety Administration
Jeffrey Hickman	Virginia Tech Transportation Institute - Center for Truck and Bus Safety
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Dinkar Mokadam	Association of Flight Attendants-CWA
David Moore	Volpe The National Transportation Systems Center
Mary O'Connor	NIOSH
Ryan Olson	Oregon Health & Science University
Stephen Popkin	Volpe, The National Transportation Systems Center
Michael Quinlan	University of New South Wales
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Brian Sherlock	Transport Worker's Union of America AFL-CIO
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Karl Sieber	NIOSH
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Mike Trusty	Wal-mart
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Transport Worker's Union of America AFL-CIO

Owner Operator Independent Drivers Association, Foundation

Ben E. Keith Company

Southwest

APPENDIX B: STRATEGIC GOAL WORKGROUPS AND AUTHORS

Objective 1: Reduce deaths and injuries of TWU workers

Terry Bunn, Jennifer Lincoln (WV), Guang Chen, Mary O'Connor

Objective 2: Reduce musculoskeletal disorders among TWU workers

Dinkar Mokadam, Jennifer Lincoln (WV), Brian Sherlock, Eric Wood

Objective 3: Promote and improve the health and well-being of TWU workers

Jeff Hickman, Jennifer Lincoln (AK), Karl Sieber, Rafael Lefkowitz, Eric Wood, Enjoli DeGrasse, Ryan Olson

Objective 4: Increase knowledge about the association between TWU worker exposures and adverse health outcomes, and effective prevention and control strategies

Dan Flinta, Karl Sieber, Rafael Lefkowitz, Brian Sherlock

Objective 5: Increase knowledge about the role of worker characteristics and impairment on TWU worker safety, health and well-being, and effective prevention strategies

Karl Sieber, David Moore, Don Fisher, Robin Gillespie

Objective 6: Encourage Prevention through Design to improve the safety of work environments, equipment, and tasks

Jack Sahl, Dinkar Mokadam, Brian Sherlock, Jennifer Lincoln (WV)

Objective 7: Proactively address the safety implications of emerging technologies

Dawn Castillo, David Moore, Don Fisher, Enjoli DeGrasse

Objective 8: Support safe workplaces through organizational-level factors, programs, and measures

Kim Davies-Schrils, Jack Sahl, Dinkar Mokadam, David Moore, Steve Popkin, Dan Flinta

Objective 9: Increase understanding of how changes in the economy affect the safety and well-being of TWU workers

Jennifer Lincoln (AK), Tim Bushnell

Objective 10: Foster translation of research into practice to improve the health and well-being of TWU workers

Mark Friend, Steve Popkin, Liz Dalsey, Karl Sieber, Kim Davies-Schrils, Rafael Lefkowitz, Robin Gillespie