



Provincial Underground Mining Sector Risk Assessment
Workshop Results
A focused approach to improving workplace health & safety

Table of Contents

RA = risk assessment

U/G = underground

1. **RA:** Introduction
2. **The Swiss Cheese Model of Accident Causation**
3. **Workshop:** A Tripartite and Collective Process
4. **RA Workshop:** Attendees
5. **RA Workshop:** Event Categories
6. **U/G Mining Sector Risk Assessment:** Heat Map
7. **U/G Mining Sector Risk Assessment:** Top 10 of 54 Identified Risks
8. **U/G Mining Sector Risk Assessment:** Top 10 risk categories based on the highest risk within that category
9. **Worker vs. Workshop Results:** Comparison of their Top 10 Risks
10. **Employer vs. Workshop Results:** Comparison of their Top 10 Risks
11. **RA:** Prioritize Risks
12. **Appendix A:** Workshop Process Details
13. **Appendix B:** Risk Assessment Processes/Standards
14. **Appendix C:** Contacts

Risk Assessment: Introduction

- ❑ **2013: MLITSD launched project to put in place an integrated risk assessment methodology to:**
 - identify risks to worker health and safety & work with employers and workers on reducing those risks
 - provide more information to employers, workers & their representatives about risks at the **SECTOR** level

With support of the MLRC and MLITSD, WSN planned & facilitated the **Underground Mining Sector Risk Assessment**

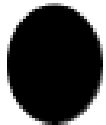
- ❑ **Harness collective wisdom across the sector in a tripartite process to focus the industry, health & safety associations (HSAs), and regulator on highest risks to health and safety**
- ❑ **Approach draws on industry, worker, HSA, & Ministry knowledge of risk and recognizes that one-size approach does not fit all**
- ❑ **Approach draws on empirical insights of risk management & operations research/decision science**

Prevention

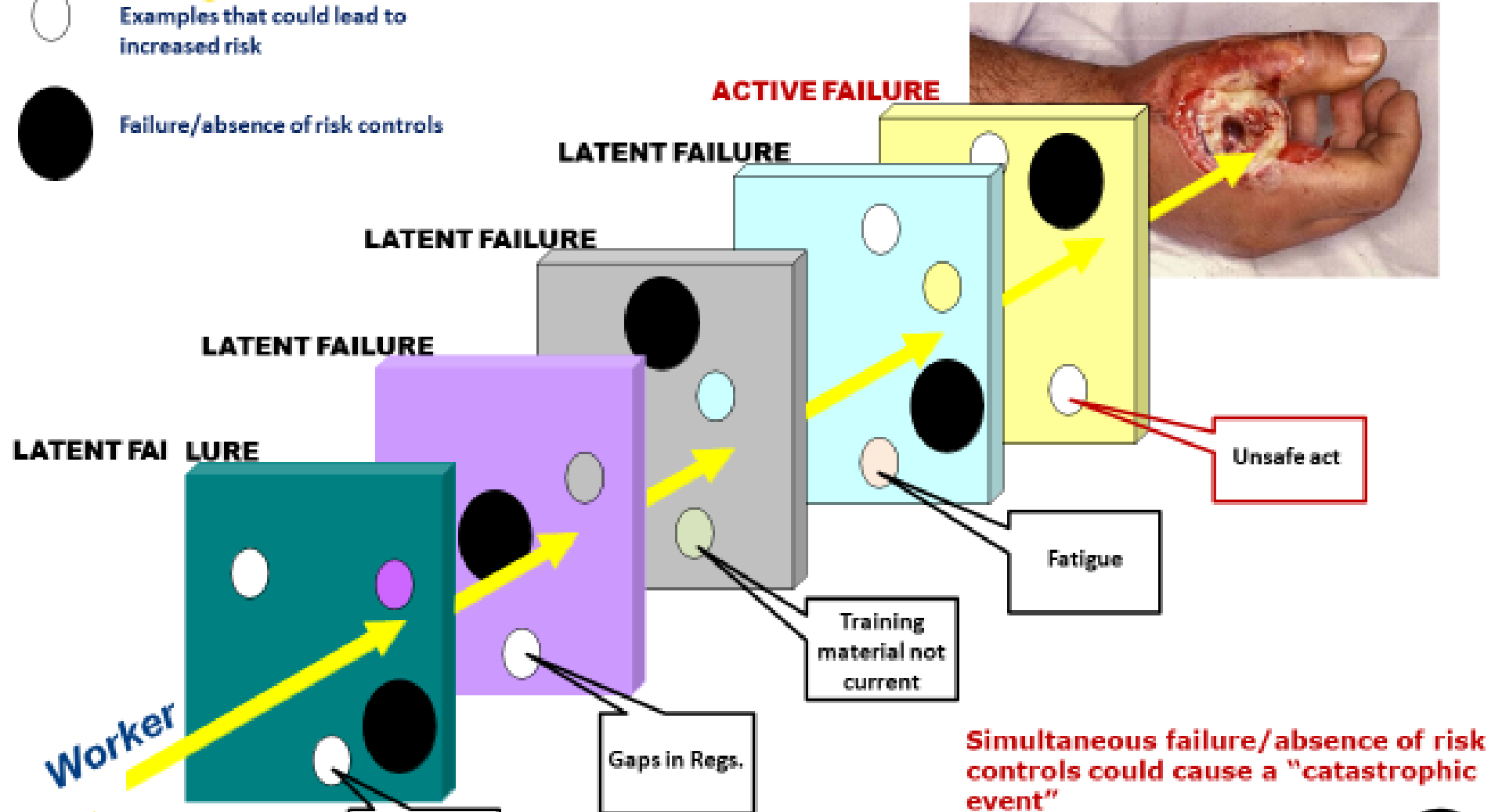
The Swiss Cheese Model of Accident Causation



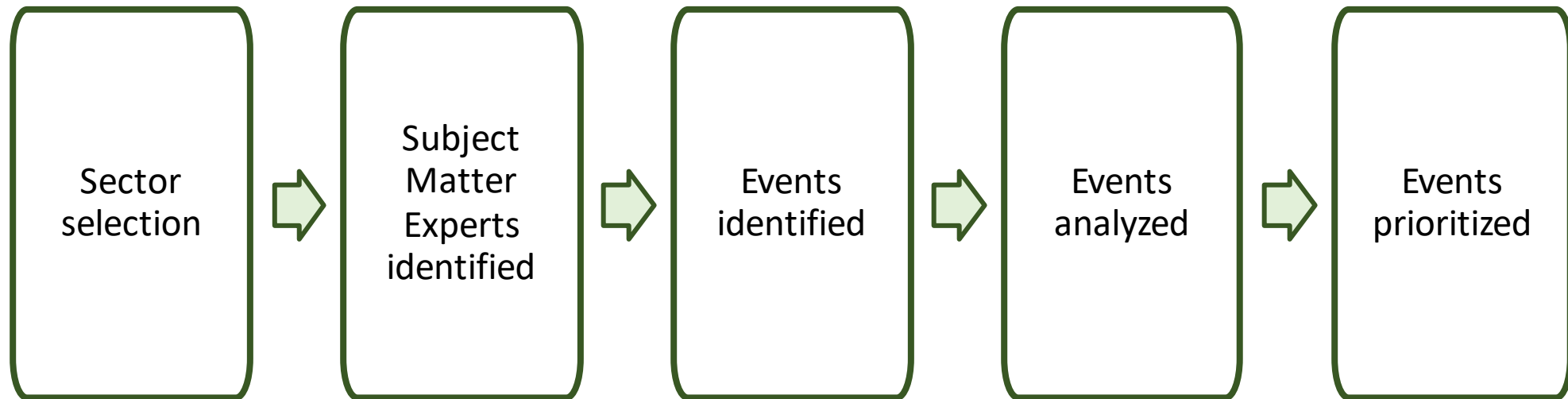
Examples that could lead to increased risk



Failure/absence of risk controls



Workshop: A Tripartite and Collective Process



Workshop: A Tripartite and Collective Process

Workshop process was open, transparent, and collaborative:

- Ensured any perspective or viewpoint was heard
- Each response received was respected and not freely edited
- Final list shared with workshop participants before the workshop
- Final workshop results reviewed/validated by industry participants

Finding acceptable solutions that all members can support:

- Only industry experts ranked the risks, not government or WSN
- Process was NOT about consensus, although the results demonstrate a significant degree of convergence



Risk Assessment Workshop: Attendees

| SUBJECT MATTER EXPERTS | | |
|------------------------|-----------------|------------------------|
| # | Name | Company/Representative |
| 1 | Craig Allair | Vale |
| 2 | Richard Claveau | Newmont |
| 3 | Nav Gill | KGHM |
| 4 | Billy Smith | Glencore |
| 5 | Jerry Thibeault | Vale |
| 6 | Chris Betsill | Redpath |
| 7 | Loye Halteman | Barrick |
| 8 | Jake Hughes | Technica |
| 9 | Michelle Hulme | Vale |
| 10 | Darren Raymond | Compass Minerals |

| WORKSHOP PARTICIPANTS | | |
|-----------------------|-----------------|---------------------------------------|
| # | Name | Company/Representative |
| 1 | Derek Budge | Mining Legislative Review Committee |
| 2 | Malcom Mills | Mining Legislative Review Committee |
| 3 | Rick Legree | Barrick: Worker Advisor |
| 4 | Scott Secord | MLITSD: Inspector |
| 5 | Tom Welton | Workplace Safety North: Tech Support |
| 6 | Robert Marin | Workplace Safety North: Facilitator |
| 7 | Sam Barbuto | Workplace Safety North: Facilitator |
| 8 | Tiana Larocque | Workplace Safety North: Tech Support |
| 9 | Tricia Valentim | Workplace Safety North: Tech Support |
| 10 | Harsim Kalsi | MLITSD: Provincial Mining Coordinator |

MLITSD: Ministry of Labour, Immigration, Training, and Skills Development

Worker Representation

Employer Representation



Risk Assessment Workshop: Event Categories

1. Equipment, materials, machinery
2. Fire and explosion
3. Musculoskeletal disorder hazards
4. Ground Control
5. Occupational illness/disease
6. Environment
7. Psychosocial hazards
8. New/young workers
9. Temperature stress
10. Work practices
11. Water management
12. Shaft hazards

Risk Assessment: Prioritize risks

- The purpose of this stage is to assess the level of risk and establish risk priorities
- **Risk**, which is the **average Likelihood (L)** multiplied by the **average Consequence (C)** for each event, then is categorized with respective risk ratings using the **Risk Matrix (Heat Map)**

| | | | | | | |
|-------------------|--------------------|--------------------|-----------|--------------|-----------|-------------|
| LIKELIHOOD | Almost Certain (5) | 5 | 10 | 15 | 20 | 25 |
| | Very Likely (4) | 4 | 8 | 12 | 16 | 20 |
| | Likely (3) | 3 | 6 | 9 | 12 | 15 |
| | Unlikely (2) | 2 | 4 | 6 | 8 | 10 |
| | Rare (1) | 1 | 2 | 3 | 4 | 5 |
| | | Low (1) | Minor (2) | Moderate (3) | Major (4) | Extreme (5) |
| | | CONSEQUENCE | | | | |

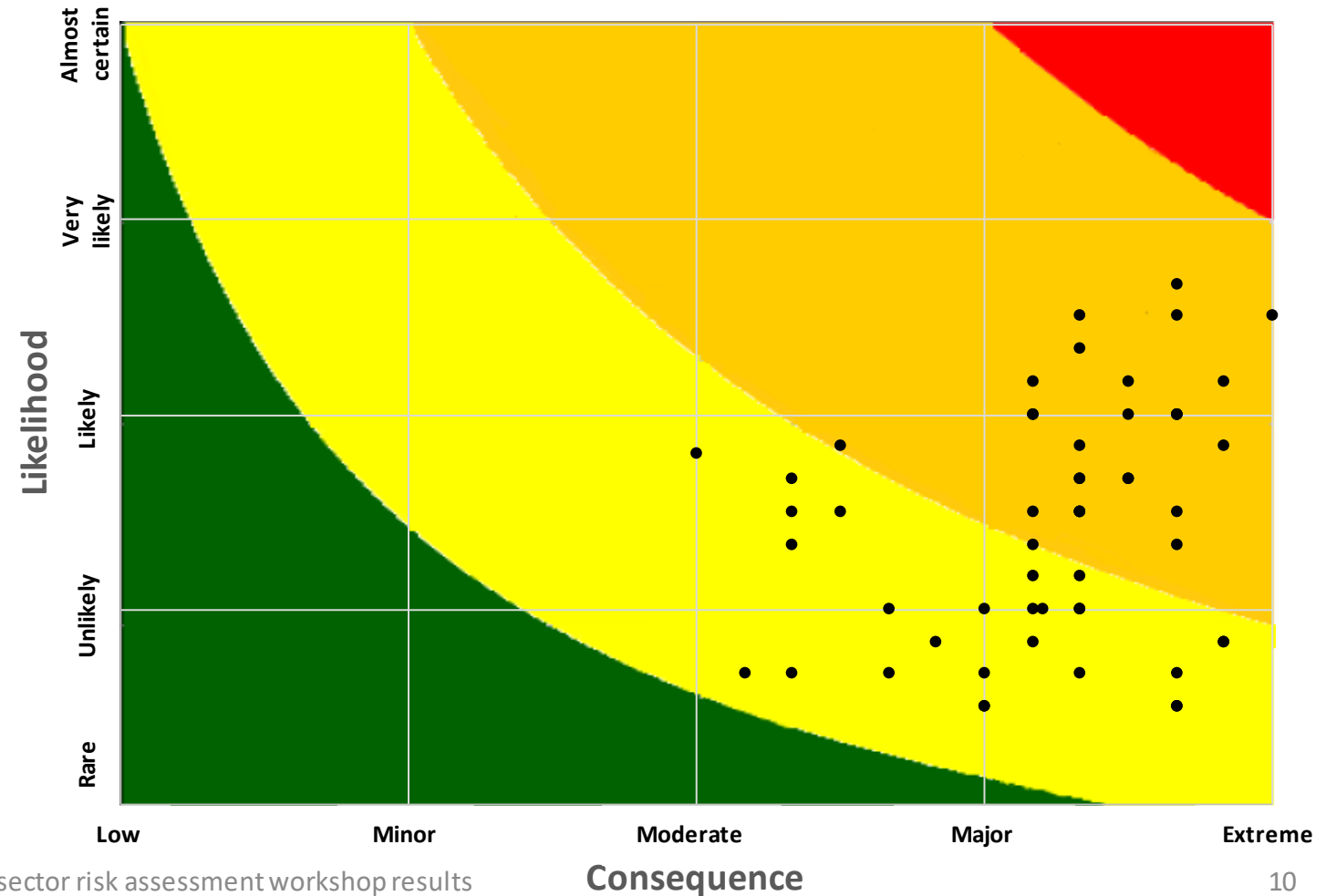
| Risk Matrix Result | Risk Rating |
|--------------------|-------------|
| 20 to 25 | Critical |
| 12 to 16 | High |
| 5 to 10 | Moderate |
| 1 to 4 | Low |

U/G Mining Sector Risk Assessment: Heat Map

| Risk Rating |
|-------------|
| Critical |
| High |
| Moderate |
| Low |

| Likelihood | Description |
|--------------------|--|
| [1] Rare | Very low probability for unwanted event to occur in the next year [or less than 5% of occurrence] |
| [2] Unlikely | Low probability for unwanted event to occur in the next year [or between 5%-20% chance of occurrence] |
| [3] Likely | It is possible for unwanted event to occur in the next year [or between 20%-50% chance of occurrence] |
| [4] Very likely | High probability for unwanted event to occur in the next year [or between 50%-90% chance of occurrence] |
| [5] Almost certain | Unwanted event is almost certain to happen in the next year [or 90% or greater chance of occurrence] |

| Consequence | Description |
|--------------|---|
| [1] Low | No injury or illness [or negligible impact/importance] |
| [2] Minor | First aid treatment (no lost time) [or minor impact/importance] |
| [3] Moderate | Temporary disability (lost time): Injury/illness [or moderate impact/importance] |
| [4] Major | Serious event/critical injury or critical illness [or major impact/importance] |
| [5] Extreme | Fatality or permanent disability [or extreme impact/importance] |



U/G Mining Sector Risk Assessment: Top 10 of 54 identified events

| Rank | Category | Event (Situation/Condition) that could result in Injury or Illness OR What could keep you up at night? | Risk |
|------|----------------------------------|--|-------|
| 1 | Equipment, materials, machinery | Interaction with Mobile Equipment – Equipment collision with other equipment (Large vs small) - Traffic Control | 19.78 |
| 2 | Equipment, materials, machinery | Interaction with Mobile Equipment and pedestrian | 17.60 |
| 3 | Fire and explosion | Adoption of new Technology: Battery Electric Vehicle Fires - Battery electric vehicle overheats, catches fire, or explodes underground (injuring operators, miners and/or mine rescue personnel) | 15.12 |
| 4 | Musculoskeletal disorder hazards | Worker suffers manual handling or repetitive strain injury | 15.04 |
| 5 | Ground control | Ground control failure causing injury | 14.80 |
| 6 | Occupational illness/disease | Exposure to airborne hazardous substances | 14.80 |
| 7 | Equipment, materials, machinery | Interaction with Mobile Equipment – collision with infrastructure (conveyors, towers, etc.) | 14.62 |
| 8 | Equipment, materials, machinery | Inadvertent contact with stored energy | 14.62 |
| 9 | Occupational illness/disease | Hearing loss | 14.52 |
| 10 | Fire and explosion | Major fire underground from mobile Equipment | 13.76 |

U/G Mining Sector Risk Assessment: Top 10 risk by category

| Rank | Category | Event (Situation/Condition) that could result in Injury or Illness OR What could keep you up at night? |
|------|----------------------------------|--|
| 1 | Equipment, materials, machinery | Interaction with Mobile Equipment – Equipment collision with other equipment (Large vs small) - Traffic Control |
| 2 | Equipment, materials, machinery | Interaction with Mobile Equipment and pedestrian |
| 3 | Fire and explosion | Adoption of new Technology: Battery Electric Vehicle Fires - Battery electric vehicle overheats, catches fire, or explodes underground (injuring operators, miners and/or mine rescue personnel) |
| 4 | Musculoskeletal disorder hazards | Worker suffers manual handling or repetitive strain injury |
| 5 | Ground control | Ground control failure causing injury |
| 6 | Occupational illness/disease | Exposure to airborne hazardous substances |
| 7 | Equipment, materials, machinery | Interaction with Mobile Equipment – collision with infrastructure (conveyors, towers, etc.) |
| 8 | Equipment, materials, machinery | Inadvertent contact with stored energy |
| 9 | Environment | Hearing loss |
| 10 | Fire and explosion | Major fire underground from mobile Equipment |

Worker vs. Workshop Results: Top 10 comparison

| # | Category | Event (Situation/Condition) that could result in Injury or Illness OR What could keep you up at night? | RISK |
|----|----------------------------------|--|-------|
| 1 | Occupational illness/disease | Exposure to airborne hazardous substances | 20.30 |
| 2 | Equipment, materials, machinery | Interaction with Mobile Equipment – Equipment collision with other equipment (Large vs small) - Traffic Control | 19.17 |
| 3 | Equipment, materials, machinery | Interaction with Mobile Equipment and pedestrian | 17.50 |
| 4 | Equipment, materials, machinery | Interaction with Mobile Equipment – collision with infrastructure (conveyors, towers, etc.) | 14.57 |
| 5 | Fire and explosion | Adoption of new Technology: Battery Electric Vehicle Fires - Battery electric vehicle overheats, catches fire, or explodes underground (injuring operators, miners and/or mine rescue personnel) | 14.67 |
| 6 | Musculoskeletal disorder hazards | Worker suffers manual handling or repetitive strain injury | 14.40 |
| 7 | Fire and explosion | Worker caught in smoke | 13.20 |
| 8 | Fire and explosion | Major fire underground from mobile Equipment | 14.40 |
| 9 | Equipment, materials, machinery | Inadvertent contact with stored energy | 14.40 |
| 10 | Environment | Contagious infections, flu etc. | 13.33 |

Worker results

| # | Category | Event (Situation/Condition) that could result in Injury or Illness OR What could keep you up at night? | RISK |
|----|----------------------------------|--|-------|
| 1 | Equipment, materials, machinery | Interaction with Mobile Equipment – Equipment collision with other equipment (Large vs small) - Traffic Control | 19.78 |
| 2 | Equipment, materials, machinery | Interaction with Mobile Equipment and pedestrian | 17.60 |
| 3 | Fire and explosion | Adoption of new Technology: Battery Electric Vehicle Fires - Battery electric vehicle overheats, catches fire, or explodes underground (injuring operators, miners and/or mine rescue personnel) | 15.12 |
| 4 | Musculoskeletal disorder hazards | Worker suffers manual handling or repetitive strain injury | 15.04 |
| 5 | Ground control | Ground control failure causing injury | 14.80 |
| 6 | Occupational illness/disease | Exposure to airborne hazardous substances | 14.80 |
| 7 | Equipment, materials, machinery | Interaction with Mobile Equipment – collision with infrastructure (conveyors, towers, etc.) | 14.62 |
| 8 | Equipment, materials, machinery | Inadvertent contact with stored energy | 14.62 |
| 9 | Environment | Hearing loss | 14.52 |
| 10 | Fire and explosion | Major fire underground from mobile Equipment | 13.76 |

Workshop results

Employer vs. Workshop Results: Top 10 comparison

| # | Category | Event (Situation/Condition) that could result in Injury or Illness OR What could keep you up at night? | RISK | # | Category | Event (Situation/Condition) that could result in Injury or Illness OR What could keep you up at night? | RISK |
|----|----------------------------------|--|-------|----|----------------------------------|--|-------|
| 1 | Equipment, materials, machinery | Interaction with Mobile Equipment – Equipment collision with other equipment (Large vs small) - Traffic Control | 21.16 | 1 | Equipment, materials, machinery | Interaction with Mobile Equipment – Equipment collision with other equipment (Large vs small) - Traffic Control | 19.78 |
| 2 | Equipment, materials, machinery | Interaction with Mobile Equipment and pedestrian | 18.40 | 2 | Equipment, materials, machinery | Interaction with Mobile Equipment and pedestrian | 17.60 |
| 3 | Ground control | Ground control failure causing injury | 17.60 | 3 | Fire and explosion | Adoption of new Technology: Battery Electric Vehicle Fires - Battery electric vehicle overheats, catches fire, or explodes underground (injuring operators, miners and/or mine rescue personnel) | 15.12 |
| 4 | Environment | Hearing loss | 16.56 | 4 | Musculoskeletal disorder hazards | Worker suffers manual handling or repetitive strain injury | 15.04 |
| 5 | Musculoskeletal disorder hazards | Worker suffers manual handling or repetitive strain injury | 15.36 | 5 | Ground control | Ground control failure causing injury | 14.80 |
| 6 | Fire and explosion | Adoption of new Technology: Battery Electric Vehicle Fires - Battery electric vehicle overheats, catches fire, or explodes underground (injuring operators, miners and/or mine rescue personnel) | 15.20 | 6 | Occupational illness/disease | Exposure to airborne hazardous substances | 14.80 |
| 7 | Equipment, materials, machinery | Inadvertent contact with stored energy | 14.72 | 7 | Equipment, materials, machinery | Interaction with Mobile Equipment – collision with infrastructure (conveyors, towers, etc.) | 14.62 |
| 8 | Equipment, materials, machinery | Interaction with Mobile Equipment – collision with infrastructure (conveyors, towers, etc.) | 13.80 | 8 | Equipment, materials, machinery | Inadvertent contact with stored energy | 14.62 |
| 9 | Fire and explosion | Major fire underground from mobile Equipment | 13.44 | 9 | Environment | Hearing loss | 14.52 |
| 10 | Ground control | Uncontrolled run of muck | 12.92 | 10 | Fire and explosion | Major fire underground from mobile Equipment | 13.76 |

Employer results

Workshop results

Appendix A: Workshop Process Details

1. A sector is identified and defined for risk assessment
2. Subject matter experts (SMEs) from the selected sector are identified
3. Each of the selected SMEs list (identify) the situations or conditions (events) that could lead to injury or illness with appropriate evidence for each event (pre-workshop)
4. The lists are collected and amalgamated into one list (pre-workshop)
5. The amalgamated list is sent to each SME for review (pre-workshop)
6. A workshop is scheduled for the analysis and prioritization of each identified event on the amalgamated (final) list
7. Workshop conducted in blended face-to-face and videoconferencing format in light of necessary COVID-19 pandemic precautionary measures.
8. For each identified event on the list, SMEs contribute toward a robust discussion, generating deeper objective understanding and allowing for all perspectives to be heard (comments are NOT attributed)
9. After each discussion for each identified event, each SME “votes” (based on identified criteria/scale) to lock in a value judgement on **likelihood of the event occurring** and **severity of the consequence if the event was to occur**
10. Electronic voting tools are used to make voting easy and anonymous; results on each event are instantaneous
11. Project manager takes results to create a risk profile/heat map for the sector
12. Results validation includes “smell test” by industry SMEs before releasing final results

Appendix B: Risk Assessment Processes/Standards

1. Bayesian Analysis
2. Bow-tie analysis
3. Brainstorming (e.g. what-if)
4. Business impact analysis
5. Cause and effect analysis
6. Checklists
7. Computer Hazard and Operability Studies (CHAZOP)
8. Consequence Analysis (also called Cause-Consequence Analysis)
9. Likelihood/Consequence matrix
10. Construction Hazard Assessment and Implication Review (CHAIR)
11. Decision tree
12. Delphi technique
13. Energy Barrier Analysis (or Energy Trace Barrier Analysis)
14. Environmental risk assessment
15. Event tree analysis
16. Failure Mode and Effect Analysis (FMEA)
17. Failure mode, effect and criticality analysis
18. Fault Tree Analysis
19. Fishbone (Ishikawa) Analysis
20. Hazard analysis and critical control points
21. Hazard and Operability studies (HAZOP)
22. Human reliability analysis
23. Job Safety Analysis (JSA)
24. Level of Protection Analysis (LOPA)
25. Markov analysis
26. Monte Carlo
27. Preliminary Hazard Analysis (PHA)
28. Reliability centered maintenance
29. Scenario analysis
30. Sneak circuit analysis
31. Structured/semi-structured interviews
32. SWIFT (i.e. structured what-if)
33. Systemic Cause Analysis Technique (SCAT)
34. Human Error Analysis (HEA)
35. Workplace Risk Assessment and Control (WRAC)

Risk Management Standards:

1. Risk Management Principles and Guidelines (ISO 31000:2009)
2. Risk Assessment Techniques (ISO/IEC 31010:2009)
3. OH&S Hazard Identification and Elimination and Risk Assessment and Control (CSA Z1002)
4. Process Safety Management (CSA Z767-17)
5. Enterprise Risk Management (COSO 2004)
6. Global Minerals Industry Risk Management (GMIRM)
7. International Council on Mining & Metals (ICMM)

*** Not an exhaustive list**

Appendix C: Contacts

For additional information or questions, please contact:

Robert Marin

Open Pit and Surface Plants Health and Safety Specialist

Workplace Safety North

RobertMarin@workplacesafetynorth.ca

Sam Barbuto

Health and Safety Specialist

Workplace Safety North

SamBarbuto@workplacesafetynorth.ca