AMSA

Alberta Mine Safety Association

Guidelines

Autonomous Haul System (AHS)

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Acknowledgments

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Table of Contents

Introduction

Workplace health and safety is paramount in the mining industry. Autonomous Technology in Alberta Mines – a health and safety guide provides direction for the healthy and safe application and operation of autonomous technology in mining in the Province of Alberta. This document presents a proactive structure for hazard identification, mitigation, and on-going management of potential hazards at the work site related to autonomous technology. It will provide a common communication and collaboration structure for equipment and technology providers, employers, workers, and regulators.

This guide is intended for those responsible for the implementation, operation, and maintenance of autonomous mining equipment. However, the information provided is useful to anyone who works with or around autonomous technology.

The scope of application for this guide includes: mobile autonomous/semi-autonomous, and remote-control systems used for surface and underground mining/quarries, such as:

- haul trucks including rigid frame and articulated trucks,
- loading tools including rope shovels, hydraulic excavators, hydraulic front shovels, wheel loaders, and load-haul-dump machines,
- drills,
- wheel and track dozers, and
- water trucks, motor graders, floats, scrapers, or other auxiliary equipment.

This guide is not intended to apply to the following:

- Unmanned aerial vehicles.
- Explosive atmosphere requirements.
- Machines that rely on fixed infrastructure (e.g. rails, trains, reclaimers, stackers).
- Stationary equipment, such as processing plants, conveyors, etc…

This document does not account for all conditions and emerging technologies. It is the responsibility of the operator of the technology to ensure appropriate controls are in place to identify hazards and address specific situations. Alternate approaches that deliver the same level or greater health and safety may be considered than what is provided in this guide, as long as they meet the regulatory requirements. This guide does not apply to construction, agricultural, public transportation, and automotive applications of mobile autonomous vehicle technology.

Definitions

Autonomous – The ability to complete productive operations or tasks without human intervention. Typically, human intervention is limited to exception handling and mission planning.

Autonomous Operating Zone (AOZ) / Autonomous Operating Area – The area or zone in which autonomous or semi-autonomous equipment is intended to operate

Hazard – A situation, condition or thing that may be dangerous to the safety or health of workers.

Hazard assessment – A written process to recognize existing and potential hazards at work before they cause harm to people or property.

Mobile autonomous machine – Any mobile equipment controlled by an autonomous system

Remote-Control – The ability to provide direct human supervision and control for the operations of a machine from a station or console that is separate from the machine, either line-of-site or tele-remote.

Risk – A combination of the likelihood of occurrence or chance of a work-related hazardous event or exposure and the severity of injury and/or ill health that can be caused by the event or exposure.

Semi-autonomous – The ability to accomplish a portion of a task, or productive operation, without human intervention or direct control. Human intervention, however, is needed for a portion of this defined task. Typically, human intervention is needed to complete the primary productive operation or task.

Hazard Assessment and the ISO Risk Management Approach

The hazard assessment and control process provides a consistent approach for employers and workers to identify and control hazards in the workplace. It allows everyone to focus their efforts in the right areas, and to develop worker training, inspections, emergency response plans, etc. specific to the hazards at their work sites.

To implement hazard assessment and risk reduction, the employer shall take the following actions:

- determine the limits of the machinery, which include the intended use and any reasonably foreseeable misuse.
- identify the hazards and associated hazardous situations.
- estimate the risk for each identified hazard and hazardous situation.
- evaluate the risk and take decisions about the need for risk reduction.
- eliminate the hazard or reduce the risk associated with the hazard by means of protective measures.

Operators can follow the principles of risk assessment and risk reduction outlined in ISO 12100 to demonstrate that potential hazards are controlled. These principles are based on knowledge and experience of the design, use, incidents, accidents and risks associated with the autonomous mining system. Refer to ISO 12100 for:

- procedures for identifying hazards.
- procedures for estimating and evaluating risks.
- the relevant documentation to verify the hazard assessment and risk reduction process.

Risk Identification

ISO 17757 can be used to help identify risks. It is essential that the owner/operator of the autonomous projects understands that the risk identification section of the risk management plan must be updated as the project enters new phases and new risks are introduced.

It is also important for management to understand that feedback about high priority risks will come from their frontline operations personnel, thus constant engagement about risk identification between management and worker is imperative.

Introducing an Autonomous Haulage System (AHS) into a previously manned operation introduces a new set of risk to operations and maintenance personnel. It is important that all personnel who enter the AOZ go through in-depth training, and are deemed competent by a certified trainer of the autonomous system. Some of the risks while working within area are outlined in the following table of examples.

People Risks	Process Risks	Technology Risks
Improper use of the system leaving personnel undetected and or unprotected	Infrastructure risk	Internet security, cyber criminality data privacy breaches, vulnerabilities in system getting exposed
Inadequate training or time to build necessary habits to operate safely in AOZ	Information technology risk	Lack of Information
Lack of adequate communication between operations and management about changes taking place in the AOZ	Human error	Supplier of autonomous system no longer in business or available to provide tech support
Exposure limits to control room operators and technical support staff working in or near server rooms and with high level emission of electromagnetic fields	Mechanical failure	System not designed for application
	Quality control of operations	Communication challenges due to satellite transmissions

Risk Analysis

Analysis and review of risks should be gauged through factors such as likelihood of an incident, frequency and levels of severity as can be seen in ISO 12100. The person conducting risk analysis must have a complete understanding of the automation system functionality so they can properly assess risk potential.

Risk Evaluation

Risk evaluation should be conducted to determine if assets such as personnel, equipment or systems are at risk:

1. Identify potential risks; people, technology, process and then prioritize which risks to pursue first. Locate assets and trace risk back to its source e.g. training, procedures.
2. Estimate the probability and impact of each risk using a risk matrix, or something similar, to identify the probability or likelihood against the category of consequence severity.
3. Identify and list conditions that cause the risk to occur.

4. Risk treatment requires the management group to acknowledge that the risk exists, implement mitigation plans, and once risk is mitigated plan for future re-evaluation.

5. Determine if any new risks were introduced through mitigation plans of original risks. If so evaluate those new risks.

6. Conduct assessment of remaining risks after mitigation plans have been introduced.

7. Schedule monitoring and review of mitigation plans to ensure plan still fits scope of work.

Risk management

Operational risks can compromise the day-to-day operations of an autonomous project. Although the operation is autonomous, there is a human element that must be accounted for so the operation can run safely. This risk can be managed through an organization willingness to:

- give workers the training and time to build the necessary skill sets to operate within the AOZ safely
- commit to regular discussions about automation project challenges and collaborate management strategies with front line workers.
- apply best practice and sharing of information from previous autonomous operations for learning and to support new challenges within the autonomous project

Monitoring and review

Key to the sustainability of autonomous mining is risk monitoring and review through regular site inspections (e.g. quarterly) of the autonomous area, system audits and mock emergency response exercises. Task forces and committees, should periodically review work practices and procedures to ensure that they still fit the scope of work.

Documentation

Organizations need to take specific actions to demonstrate sufficient effort to manage risk. This includes recording efforts to meet any obligations laid out in relevant regulation and guidelines. Examples of these documents include risk registers, project management plans and consultation logs. Information to be recorded includes:

- Documentation to be captured to demonstrate:
  - Identification of risks and mitigations,
  - Effective incident and emergency management,
  - Updated work practices, for example procedures,
  - Workforce competency, and
  - Stakeholder engagement and communications.
- Collation of relevant information into a project management plan (PMP), including but not limited to:
  - Operational context
    - General site overview
    - Technology overview
    - Where applicable reference relevant demonstrated performance
  - Implementation plan (that details)
    - Where?
    - How?
    - When?
    - Scale of the implementation?
    - Demonstration of risk mitigation. For example, if segregation is a mitigation, the implementation plan should demonstrate how segregation will be executed.
  - Risk Management
    - Overview of risk management approach taken – fit for purpose
    - Original equipment manufacturer and worker involvement
    - Safety committee involvement
- Risk assessment outcomes - risks and mitigations
- Appendices

Autonomous Implementation Stages

Implementation of autonomous technology occurs in three stages: pre-implementation, implementation and operation. This section describes each stage and the types of hazards that may exist during that stage.

Pre-Implementation

The pre-implementation stage of work is the technology evaluation stage. This stage may see the autonomous technology used at a non-full scale operation for evaluation purposes. Completion of the pre-implementation stage typically leads to a decision whether the technology is implemented.

The stages of pre-implementation will vary depending on the technology being considered and may include:

- proof of concept.
- analysis and simulation testing.
- field engineering testing.
- commercial scale testing.

Develop an evaluation plan that clearly identifies the scope of the evaluation and the work required to support it. The plan should include hazard assessments to identify the risks to health and safety and the required controls to be put in place. Examples of potential hazards are included in the following table.

People Readiness	Equipment Readiness	Infrastructure Readiness	Business Readiness
Worker training for those involved in Pre- implementation	Primary equipment technology installation	Communications network	Operating procedures
Stakeholder communications	Support equipment technology installation	Mine area infra-structure such as roads, mine access locations, mine access controls	Emergency managemen t
	Technology testing and commissioning		

Implementation

The implementation stage of work is the installation of the autonomous technology and preparing for full scale operation. This includes system software changes.

An Implementation plan should consider the work required to support full scale operation of the technology. In many cases the primary areas of consideration will be the same as the pre-implementation stage of work however the scale of the scope, hazards and mitigations identified may be larger.

The implementation plan should incorporate insights from the Pre-implementation stages of work and the completion of hazard assessments.

The hazard assessments should identify the risks to worker health and safety and the required controls to be put in place to mitigate these hazard during full scale operation of the technology. Examples of potential hazards can include:

People Readiness	Equipment Readiness	Infrastructure Readiness	Business Readiness
Internal and external stakeholder engagement and communications plan	Technology system installation, field equipment installation – Heavy Mobile Equipment, auxiliary and support equipment	Communications network –testing and commissioning	Procedures
Training for all related workers working with the AHS technology	Technology testing and commissioning	WIFI System	Incident management
Worker competency test		Additional infra-structure – roads, operating locations, access gates	Emergency management
Functional support areas – IT, HR, Procurement etc.		Changing infra-structure - bench widths, fueling areas, laydown areas, maintenance areas	

Operations

The operations stage of work is the stage where the autonomous technology is in full operation following a successful implementation stage. The transition from implementation to operation may require a phased approach depending on the technology and degree of operational change.

During this stage the full scale operation of the technology will provide ongoing insights to support operational and technology improvements. For example:

- incident investigations involving related workers, safety committee's, etc
- field level hazard assessments.
- field observations.
- worker feedback.
- performance monitoring and analysis.

Operational and technology improvements may include:

- updated procedures.
- infra-structure enhancements – new access gates, signage.
- technology enhancements – new hardware, new functionalities.

Risk management is crucial to ensure new hazards are identified and mitigations are put in place during the Operations stage. For example:

- Procedures updates – communicated, training documentation updated where required, training is provided to workers where required.
- Infra-structure enhancements – communicated, procedures updated where required.
- Technology enhancements – communicated, tested, procedures updated where required, training documentation updated where required, training is provided to workers where required.

References

- ISO 12100 - Safety of machinery — General principles for design — Risk assessment and risk reduction.
- ISO 17757 – Autonomous and semi-autonomous machine system safety.