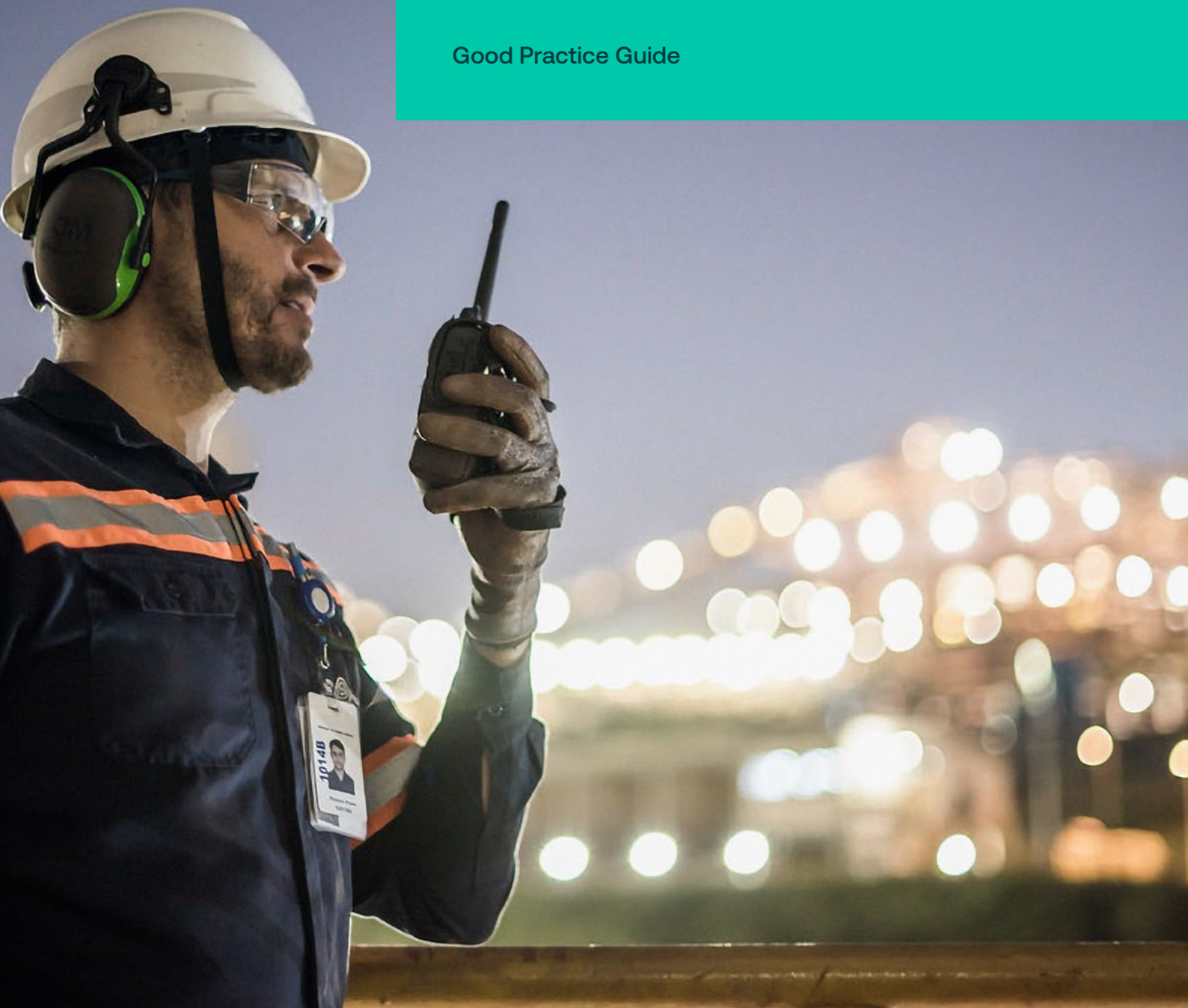
ICMM Mining with Principles

# Critical Control Management

Good Practice Guide



# Contents

# Foreword

01

Ten years ago, ICMM first published our Critical Control Management Good Practice Guide and Implementation Guidance to focus on what matters most – preventing serious harm and saving lives.

Since then, they have become two of our most widely used resources, and our members have made significant progress in reducing fatalities, showing what is possible when critical controls are well designed and diligently applied.

Yet, in the past two years that progress has faltered. Our most recent Safety Performance Report revealed fatalities among member companies have risen for a second consecutive year – in 2024 alone, 42 people lost their lives at work. That's simply unacceptable. Behind each of those lives lost are families, colleagues, and communities who are living without their loved ones.

This is not a failure of knowledge. Of those fatalities, many are associated with gaps in effective application of critical control management processes. This points to a clear need for improvement. While critical controls are widely recognised, their consistent and effective design and implementation remains a challenge. In other words, safety depends on the proper application and ongoing maintenance of these controls; when they are neglected or poorly managed, incidents are more likely to happen.

These losses have prompted deep reflection across ICMM and our members. They remind us that safety is created by people who believe, act and lead with safety at the core of every decision. We must make this the norm and move from a mindset of 'identify and document' to one of 'verify and act' – embedding critical control management into daily habits, leadership priorities and organisational culture.

That is why, a decade on, ICMM has updated our two separate guidance documents on critical controls – combining them into a single, more accessible document to better support industry implementation. This edition reflects how our understanding has matured, providing stronger direction on planning, governance, accountability and leadership involvement, introducing new tools such as maturity assessments and readiness checks. But above all, it places greater emphasis on organisational culture and frontline engagement, recognising that safety performance depends as much on people and behaviours as on process.

This publication serves to deliver guidance that is more than a revision: it is a renewed commitment – to the people who work in our industry, their families, and every community that depends on mining. We have the knowledge, tools, and above all, dedication to eliminate fatalities from our industry.

Recognising those colleagues whose lives have been lost drives us to do better. I encourage every leader, supervisor, and worker across our industry to use this guidance as a catalyst for action – to test, verify, and strengthen the controls that keep people safe and returning to their loved ones.

**Rohitesh Dhawan**, President & CEO, ICMM

# Introduction



Mining and metals operations involve complex activities, dynamic environments, and high-consequence hazards.

At the centre of this activity is a moral responsibility to protect people from life-altering injuries, fatalities, and other catastrophic events with far-reaching consequences.

Advances in engineering controls, technology, systems, and monitoring have strengthened risk management, yet people can still be exposed to serious health and safety hazards that, if not properly controlled, can result in life-altering injuries, fatalities or and other catastrophic events. Such events also disrupt operations and harm an organisation's reputation, but the primary duty remains to safeguard lives – which is why critical control management (CCM) is essential.

Over the past decade, ICMM member companies have reported improved safety performance through traditional lagging indicators, such as total recordable injury frequency rate (TRIFR). However, severe incidents – including fatal events and significant chronic health exposures – continue to occur. This underlines the limits of relying on injury metrics and related actions to manage the most serious hazards and highlights the need to focus on controls.

A control directly prevents an unwanted event or mitigates its consequences. Yet investigations of fatal and other far-reaching catastrophic events repeatedly show a recurring pattern: controls for known hazards are often missing, poorly applied, or ineffective in practice. Addressing this persistent gap is central to CCM, which provides a structured way to define the controls that matter most and are adequately designed, in place and working as intended. This is the reason for the focus on critical controls.

A critical control is one that is essential in preventing an unwanted event or mitigating its consequences. If a critical control is absent, compromised, or fails, the likelihood or severity of the unwanted event increases significantly, even when other controls are present.

This is why critical controls must be identified, implemented, and verified with a level of operating discipline that reflects their importance and strengthens the protection they provide.

## Benefits of Implementing the CCM Approach

CCM provides a clear, practical and structured process for improving control over the most serious health and safety hazards. It improves an organisation's ability to prevent fatal and other catastrophic events by increasing the reliability of the controls that protect people. By focusing on the controls with the greatest influence, CCM helps teams at all levels of an organisation direct their attention, effort and resources where they have the most impact. A CCM-centred approach also supports a strong safety culture, reinforcing operational discipline by defining how each critical control must perform and providing a structured pathway and practices to check how well it is working in practice.

It also supports greater consistency across operations by establishing common requirements and processes for critical controls. By encouraging clearer communication and meaningful conversations between frontline team members, leaders and support functions, it builds a shared understanding of critical controls and highlights issues and 'weak signals' in control performance early so they can be addressed proactively – before an incident occurs. It also supports continuous operational learning and improvement by encouraging open reporting and showing what is working well and what needs attention.

Above all, CCM is a people-centred approach. It helps protect workers from life-altering injuries, fatalities and irreversible harm. It supports leaders and teams to focus on what matters most – keeping people safe.

## ICMM's CCM Guidance

ICMM's **Health and Safety Critical Control Management Good Practice Guide** supports organisations in identifying and controlling the most serious health and safety hazards, referred to as fatal hazards, using the CCM process. It explains how to identify critical controls, how they must perform, and how to implement and verify them effectively.

The Guide provides practical guidance for organisations at any stage of their CCM journey. For those beginning the process, it offers a step-by-step approach to establishing the foundations. For organisations with existing CCM process, the updated guidance offers a way to review, revise, and strengthen current practices.

This 2026 edition of the Guide replaces two separate good practice guide and implementation guide documents published in 2015. This new, comprehensive edition introduces several key updates:

- **It integrates lessons** from a decade of member implementation and real operational experience.
- **It supports a more integrated approach** across disciplines, levels, sites, and organisations, by:
  - » providing clearer direction on planning, governance, roles, and leadership expectations
  - » placing greater emphasis on people, culture, and frontline engagement
  - » strengthening criteria for identifying controls and selecting critical controls and providing more practical guidance on defining, implementing, and verifying them
- **It introduces simple tools** – including readiness checks and a maturity assessment model – to help organisations assess effectiveness of current management practices ('state' of controls) and identify where the Guide can support improvement.

While the primary focus of the Guide is on health and safety, CCM can also be applied to other types of operational risks. Organisations may adapt the approach in ways that extend beyond the scope and terminology used in this Guide.

CCM also sits within the organisation's broader risk management framework, so the way it connects with governance, reporting and assurance processes should be clearly understood when applying the Guide.

To apply this guidance effectively, it is important to have a clear and shared understanding of the key terms used throughout the CCM process. The following definitions provide the foundation for consistent interpretation and implementation across all roles and levels of the organisation. Additional definitions are provided throughout the Guide to enhance learning and deepen understanding of topics covered in each step.

| | |
|---|---|
| **Fatal Hazard** | A hazard that can lead to an unwanted event with the potential to result in individual or multiple fatalities or life altering illnesses. In the context of CCM, the hazards to be included in the process are those that meet the scoping criteria defined by the organisation. |
| **Unwanted Event** | A situation where a hazard is released or occurs in an unplanned way, creating the potential for harm. |
| **Consequence** | A statement describing the final impact that could occur from an unwanted event. It is usual to consider this in terms of the maximum reasonable consequence. |
| **Risk** | Risk is the combination of the likelihood that an unwanted event could occur and the severity of its potential consequences. In the CCM process, risk is understood primarily through the potential consequences of fatal hazards, rather than the perceived likelihood of those events. |

| | |
|---|---|
| **Control** | An object, human action or combination of act and object that, of itself, directly prevents an unwanted event or mitigates its consequences. Its performance can be specified, measured and verified. |
| **Critical Control** | A control for a fatal hazard, which is crucial to directly preventing an unwanted event or mitigating the consequences of the event. The absence or failure of a critical control would significantly increase the likelihood of the unwanted event or the severity of its consequence despite the existence of other controls. |
| **Critical Control Management** | A process of managing fatal hazards and unwanted events that involves a systematic approach to ensure critical controls are in place and effective. |
| **Total Recordable Injury Frequency Rate (TRIFR)** | TRIFR is the number of recordable injuries per 1 million hours worked.<br>It is calculated as:<br>TRIFR = (Number of Recordable Injuries × 1,000,000) ÷ Total Hours Worked |

# How to Use This Guide

03

# A Role-by-Role Breakdown

Health and safety is everyone's responsibility therefore everyone plays a role in the CCM process. The following Quick Guide (Table 1) is designed to help you find the information most relevant to you and your colleagues.

Table 1. Quick Guide for Your Role

| Who | What do I need to know | Where to go in Guide |
|---|---|---|
| **Everyone** | — What is CCM and the process steps?<br>— What are the key terms used in CCM?<br>— What are the roles and activities for my role? | — 'CCM overview', page 17 and 18<br>— 'Key terms', page 57<br>— 'CCM roles', page 10 and 11 and Appendix A |
| **Board and executive** | — Why should we implement the CCM process?<br>— How can I influence the scope and approach?<br>— How can I foster a positive CCM culture?<br>— How can I gain insights into the effectiveness of the critical controls?<br>— How can I judge if CCM is working? | — 'Why do CCM', page 12<br>— 'Planning the Process', Step 1 page 20<br>— Appendix B<br>— 'Evaluating and improving', Step 9 page 49<br>— 'Monitoring and reporting', page 53 |
| **Senior leaders (General managers, Functional leads)** | As above – plus:<br>— How can I assess our readiness for CCM?<br>— What is my role as a risk owner?<br>— What is my role in conducting verifications?<br>— How should I respond to gaps? | As above – plus:<br>— Appendix C<br>— 'Assign accountability', Step 6 page 40<br>— 'Verifications', Step 8, page 46<br>— 'Responding to verifications', Step 8 page 46 |
| **Operational leaders (Managers and superintendents)** | — What is my role as a control owner?<br>— How do I carry out a verification?<br>— How do I get information on the effectiveness of critical control?<br>— How should I respond to gaps? | — 'Assign accountability', Step 6 page 40<br>— 'Verifications', Step 8 page 46<br>— 'Evaluating and improving', Step 9 page 49<br>— 'Responding to verifications', Step 8, page 46 |
| **Frontline leaders and team members (Supervisors, team leaders, team, contractors)** | — Where do I get information on critical controls?<br>— How do I ensure controls are effectively implemented?<br>— How do I carry out a verification?<br>— What action do I take if critical controls are not effective? | — 'Defining performance', Step 5 page 35<br>— 'Control implementation', Step 7 page 42<br>— 'Verifications', Step 8 page 46<br>— 'Responding to verifications', Step 8 page 46 |
| **Support roles (HSE, Risk, HR, L&D, Communications, IT, etc)** | — How can I influence the approach?<br>— How does CCM fit with other approaches?<br>— How do I carry out a verification?<br>— How can I support the continuous improvement of the CCM process? | — 'Planning the Process', Step 1 page 20<br>— 'Where does CCM fit', page 13<br>— 'Verifications', Step 8 page 46<br>— 'Embedding and sustaining', page 55 |

# Critical Control Management

04

# What Are Everyone's Roles in CCM?

The successful planning, development and implementation of CCM requires everyone throughout the organisation to be engaged and play their role in the process.

This starts from the very top of the organisation and runs through to the frontline workforce who are ultimately exposed to the hazards and who implement the controls.

The typical roles in CCM are summarised in Figure 1, which distinguishes between the role of operations and line management, the support functions and those assigned as risk or control owners.

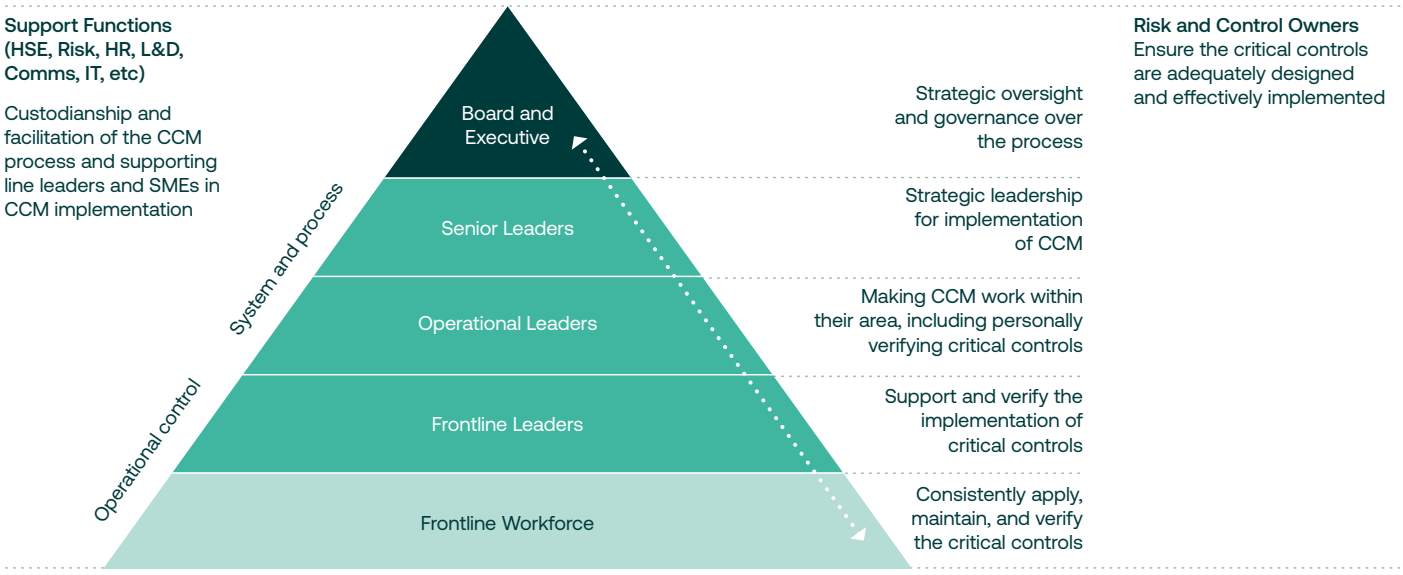
Each tier within the line of accountability includes oversight of the level below, providing a robust governance and reporting structure. A summary of the accountabilities and key actions for each role is included in Appendix A. The actual breakdown of roles and actions will depend on the context, nature and scale of the organisation.

## Who Leads CCM?

A key learning from CCM implementation is that effective delivery depends on a strong partnership between operational line management and support functions. Line management is best placed to lead the day-to-day application of CCM because they own the work, the hazards and the controls within their operational areas. Support functions – including health, safety and environment (HSE), risk, human resources (HR), learning and development (L&D) and other technical specialists – provide essential guidance, coaching and oversight, but do not replace operational ownership.

Within this structure, each organisational layer has a distinct role. The board and executive provide strategic oversight and governance of the CCM process.

**Figure 1: Typical Roles in CCM**



Senior leaders set expectations and provide strategic leadership, ensuring systems and organisational processes support CCM. Operational leaders – such as those responsible for mining, processing, maintenance or logistics – make CCM work within their area by ensuring that critical controls are clearly defined, implemented and verified. Frontline leaders, including supervisors and team leaders support and verify critical controls in day-to-day work. The frontline workforce implements critical controls in practice. Risk and control owners, are accountable for the adequacy, design and performance of specific critical controls.

In multi-site organisations, some accountabilities may also sit at the corporate level. Corporate personnel may be assigned roles such as risk owner, control owner or may provide governance, support or independent assurance over the CCM process. The allocation of these accountabilities depends on the governance model used by the organisation.

This shared approach strengthens accountability, improves integration with existing operational systems and increases the likelihood that critical controls work as intended. It ensures that operational teams lead implementation, supported by functional expertise and organisational oversight.

# How Does CCM Account for Different Hazard Types?

The mining and metals industry faces a wide range of hazards – from individual task-related hazards (e.g. falls from height) to events with potential for multiple fatalities and other large-scale and far-reaching consequences (e.g. gas explosions or tailings dam failures).

The CCM process is applicable to the full range of hazards. However, the nature of a specific hazard may influence how CCM is implemented in practice. Highly technical hazards may require specialised methodologies to identify critical controls and the involvement of subject-matter experts to verify their effectiveness. Whereas critical controls for common task-related hazards may be readily observable and able to be verified by the frontline workforce as part of the daily work management process.

For instance, it may be possible for a frontline operator and leader to directly observe and verify whether an isolation has been completed correctly, whereas verification of an automated interlock preventing overpressure depends on control systems, sensors, and transmitters, and therefore requires technical expertise.

**In other words, one approach does not fit all, and this should be considered in how CCM is designed and applied in an organisation.**

# How Does CCM Fit with Other Major Hazard and Risk Management Approaches?

## Overview of the Different Approaches

There are a wide range of approaches to managing major hazards in high-hazard industries. Key examples include process safety management (PSM) in chemical processing and safety cases for major hazard facilities (MHF). There are also approaches for specific risk areas, such as the Basic Aviation Risk Standards (BARS) for aviation and the Global Industry Standard on Tailings Management (GISTM) (2020) for tailings dams. Each establishes structured frameworks and methods to manage respective hazards.

Terminology also varies across sectors and jurisdictions. ISO 31000 refers to risk treatments and controls; upstream oil and gas uses barriers and safeguards; other frameworks reference safety-critical elements.

## What Do These Approaches Have in Common?

Despite differing methods and terminology, the approaches share core elements. In essence, all approaches aim to identify, define, implement, monitor and verify the effectiveness of the controls, even if the methods and language differ.

## How Does CCM Connect and Complement Other Approaches?

Some mining and metal industry hazards are unique to the industry and others are shared with other industries. For example, mineral processing may use hazardous materials such as ammonia and sulphuric acid, which are also used throughout the chemical processing industry. In this case, PSM, Functional Safety and allied methodologies, are well-established approaches to analysing and managing these hazards.

These established approaches complement CCM, by providing proven means to help identify and define the controls. In such cases, CCM adds value because it provides a process that brings a clear focus on the controls that are the most crucial in preventing the most severe events – the critical controls. It then provides a structured process to implement, monitor, verify, report and strengthen the effectiveness of these critical controls over time.

**Note:** The Centre for Chemical Process Safety (CCPS) has published a monograph on Process Safety for the Mining, Minerals and Metals Industry (CCPS, 2025). It aims to provide a practical, sector specific framework for applying risk based process safety (RBPS). The monograph also contains additional information about how process safety connects to CCM.

# Lessons from CCM Implementation

This section identifies some of the common challenges and lessons learnt from the implementation of CCM by ICMM member organisations over the last 10 years.

## Accurately Selecting the Critical Controls

Experience from applying the CCM guide has helped organisations sharpen their understanding of what constitutes a control and to focus more clearly on those that are truly critical, enabling them to declutter their risk management efforts. However, a review of member practices indicates a drift away from the true critical controls and the need to clearly distinguish them from the supporting activities and processes that enable them. This will help ensure that the controls identified as critical are the ones that have the greatest influence on preventing fatal and catastrophic events, addressing a common weakness where too many controls are treated as equally important. It will also help organisations prioritise implementation and verification activities on these critical controls. This Guide provides updated guidance in this area (see Steps 4 and 5).

## The Importance of Strong Workforce Engagement

The majority of members have reported on the importance of strong workforce engagement to make CCM more effective. Ensuring the involvement and 'buy-in' from the workforce is fundamental across all steps of the process to ensure the right controls are selected as critical. Furthermore, it is essential that the control performance expectations are correctly defined and there is a shared understanding of 'what good practice looks like' and reflecting these expectations in procedures and work practices.

There is no one single action that can be taken to improve workforce engagement. However, in addition to the learning example (see Step 7), the following areas should also play a part.

## The Key Role of Senior Leaders

Members have consistently reported on the essential role that leaders, particularly the most senior leaders, play in successfully implementing the approach. Leaders need to have a direct and active role in defining, reinforcing and communicating the purpose, scope and direction of the approach. This includes the review and sign-off on plans and outcomes from key process steps, and ensuring adequate resources are provided to implement CCM to a high standard.

Senior leaders also play a fundamental role in fostering the desired CCM culture, from the actions they take on a day-to-day basis. A list of suggested actions for leaders to do (and preferably avoid) in creating the desired culture to support CCM is included in Appendix B.

## Leaders' Response to Identified Gaps

Experience shows that how a leader initially responds to gaps is fundamental to building trust and encouraging the open reporting described above. Leaders need to 'respond' not 'react' to gaps. Reacting negatively to 'bad news' about critical controls will reduce the chance that personnel will report control failures. This topic is discussed further in the leaning example in Step 8 and supported by the list of suggested leader actions in Appendix B.

## Focusing on Findings

A study of mining companies carried out on behalf of a recognised industry body found that most sites track and report on the number of verifications completed (quantity) and how that compares against the planned or target number. However, there was limited feedback into what was found and actionable insights into the effectiveness of critical controls and verification activities (quality):

— what was working well
— what was not working
— how effective the critical controls are in practice
— actions being taken to improve critical controls

Identifying and acting upon signs of control failure ('weak signals') before a major incident occurs is core to the intent of CCM – as is the process of providing regular feedback to the workforce and the leaders who are responsible for driving improvement. This information is fundamental to strengthening the effectiveness of critical controls over time. Guidance on this is included in Step 9.

## Overemphasis on Personal Safety Metrics

The same study found that personal occupational safety information, including feedback on lagging incident statistics remains prominent at many sites. For example, displaying TRIFR and days since last injury on notice boards, signs at entry points and in meetings. However, by comparison there was little or no visible emphasis on the 'health' (effectiveness) of critical controls.

An example of an approach to providing feedback on critical control health to the workforce, used by an ICMM member, is provided in Step 9.

## Paying More Attention to Rare High-Consequence Events

Implementation experience has shown that CCM often focuses on the more likely fatal hazards, sometimes at the expense of the rarer multiple-fatality events that have catastrophic consequences. This highlights the need for organisations to balance attention across both high- and low-probability, high-consequence events.

The intent for CCM is to place greater emphasis on the consequence of an event, over its likelihood (risk) – 'not if, but when'. This mindset ensures the most severe events receive adequate attention throughout the organisation.

This emphasises the importance of clearly defining the purpose, scope and threshold for which hazards and unwanted events should be included in CCM and ensures the senior leaders, executives and board actively sign off the scope. Once endorsed, it is essential to stay focused and avoid shifting beyond the defined purpose and scope (see Step 1 and learning example).

## The Risks of Shortcutting Process Steps

It could be tempting for organisations to shortcut or even skip steps to reduce effort and accelerate implementation. CCM is a systematic process, so shortcutting a step risks compromising the quality and connectedness of the overall process. All steps are susceptible to this. For instance, not dedicating enough effort into developing the Critical Control Performance Specifications (Step 5) has the direct potential to result in misguided efforts in control implementation and verification.

Similarly, a process that lacks alignment and integration with wider standards, systems, processes, and operating routines for managing operational risks can threaten the ability to embed and sustain the approach over time. Maintaining this alignment over time is also essential to prevent decoupling in core areas, such as ensuring the critical controls are accurately reflected in the organisation's health and safety standards.

**The Critical Control Performance Specification** is a document that summarises the key information for a critical control, including defining its objective, performance requirements, support activities and associated verification activities. Also commonly referred to as a Summary Sheet or Performance Standard.

# Step-by-Step Outline

05

# Part 1: Overview of the Critical Control Management Process

CCM is a nine-step process, split between three phases – Planning, Development and Implementation (Figure 2).

Part 2 of this document provides step-by-step guidance and key actions for each step to meet the target outcomes detailed in Table 2. A list of the actions for each step in the process is summarised in Appendix C.

Each step might require revisiting and strengthening the previous step to achieve the desired outcome, as indicated by the feedback and improvement loop in Figure 2.

**Figure 2: The Critical Control Management Process**

Table 2. Critical Control Management Steps and Target Outcomes

| Phase | Step | Name | Target Outcome |
|---|---|---|---|
| **Plan** | 1 | Planning the process | A strategy and supporting plan that describes the scope of the project, including what is to be done, by whom and the timeframes. |
| **Develop** | 2 | Identify fatal hazards and unwanted events | Identify and summarise the fatal hazards and unwanted events to be managed. |
| | 3 | Identify controls | Identify controls for each fatal hazard and unwanted event. |
| | 4 | Select critical controls | Identify the critical controls for each fatal hazard and unwanted event. |
| | 5 | Define critical control performance | Define and summarise the critical controls' objective, performance requirements, and how they are to be supported and verified in practice. |
| | 6 | Assign accountability | Assign owners for the fatal hazards, critical controls and verification activities. |
| **Implementation** | 7 | Critical control implementation | Develop a plan to tailor the CCM content to meet local context and implement the critical controls. |
| | 8 | Critical control verification | Conduct verification activities and take corrective action as required. |
| | 9 | Evaluate and improve critical controls | Critical controls are evaluated for their effectiveness and outcomes are reported to the right people in the organisation so that appropriate actions are taken to continuously improve the critical controls. |

## Underlying Assumptions

Investigations into severe incidents commonly show that well-known controls for well-known hazards were not effectively implemented. The CCM process is built upon the following assumptions:

**Assumption 1**
The majority of fatal events within the mining and metals industry are known, as are the controls.

**Assumption 2**
Most severe incidents, including fatal events, are associated with failures to effectively implement known controls rather than not knowing what the controls should be.

**Assumption 3**
Some controls are more important than others – the critical controls. These critical controls should gain greater attention and be verified more often.

**Assumption 4**
More can be less. If everything is critical, nothing is critical. Lengthy lists of controls can be difficult to understand, implement and verify. The more succinct and specific the controls, the more robustly they can be implemented and verified.

# Part 2: The CCM Process – Step-by-Step Guidance

This section provides clear, practical guidance through each of the nine steps in the CCM process.

Each step is supported by a target outcome, key actions, guidance and a supporting learning example to demonstrate the application of the approach. A summary list of the target outcomes and actions for each step is also included in Appendix C.

**Learning Example:** This fictional learning example is used throughout the guidance to show how the nine steps of the CCM process can be applied in practice. This allows readers to understand how a company can follow the CCM process from start to finish and how each step builds on the next.

Keep an eye out in future sections for content that builds on this learning example from the perspective of fictional company East Coast Minerals' implementation of CCM guidance.

### About East Coast Minerals

East Coast Minerals Ltd (ECM) is a diversified mining company with operations in a number of different regions. They operate multiple open pit mines but recently acquired two underground operations with a shared processing facility.

### What Triggered ECM to Refresh their Approach to CCM?

A presentation to the ECM Board about the Upper Big Branch Mine disaster in West Virginia, USA raised interrogations around the changing risk profile of the business. The Board questioned whether such a serious event could happen to their own company. Listening to the Board's concerns, ECM's CEO decided to investigate the matter and report back to the Board.

As a first step, the CEO encouraged members of the senior leadership team to share their views on the topic. The responses were mixed. Some members considered that such an event was highly unlikely to happen at their operations given the significant differences with the Upper Big Branch. But others were more nuanced. One member noted that many leadership teams tend to underestimate their exposure to catastrophic events until an incident occurs. Another member pointed to some recent incidents, which in slightly different circumstances could have led to multiple fatalities. They emphasised that the incidents should be regarded as 'weak signals' of what could happen. Following this conversation, the COO was tasked to review what good practice looked like and report back to the CEO.

### How Did Internal Teams Respond?

The COO met with a selection of experienced personnel and explained that the CEO and the senior leadership wanted to hear their views.

The COO repeated the question from the CEO – 'could such an event happen to us?' Views were similarly mixed. One person pointed out that each operation had extensive and detailed hazard management plans in place. Another said that they had experienced a very low and industry-leading lost time injury frequency rate (LTIFR). Another advised that the regulator visited them regularly and had not raised any problems.

However, other views were expressed too. A production superintendent raised their concern that the hazard management plans were far too long and difficult to comprehend. The recent near-miss incidents were again raised and discussed as an indicator of what could happen. It was also apparent that there was little or no connection between a low injury rate and the probability of a fatal or other severe incident. It was discussed that an airline safety record is not judged by the injury rate of airside workers and baggage handlers but how well the aircraft are operated.

Other members pointed out that their current approach to CCM was intended to prevent these types of serious events. They talked through the background and aim of their approach, which was introduced after the publication of ICMM's CCM Guidance in 2015. The group discussed the value of the CCM approach and what it had achieved since being introduced. But they also felt their current approach could be improved and identified a few gaps:

- it is focused mainly on the task-based fatal hazards and not the rarer multiple-fatality events, as raised by the Board.
- frontline personnel had started questioning the criticality of several critical controls and the value of some of the verification activities.
- reporting to senior managers was confined to reporting on the numbers of verifications against targets, but not what they had found and what needed to be fixed, and
- the quality of the process was at risk of eroding and becoming a 'tick and flick' at the frontline.

The Underground General Manager from the newly acquired business said that they had not yet implemented CCM themselves, but some of their contractors had.

### CCM as the Path Forward

The COO reported back to the CEO relaying the key points raised by the group, emphasising the opportunities with regards to CCM, including for the new underground business. The HSE manager also advised that ICMM published an updated and improved CCM Good Practice Guide. They agreed that refreshing and expanding ECM's approach to CCM into the underground business was the best path forward.

Follow along with the next learning example

# **Step 1:** Planning the Process

**Target Outcome:** A strategy and supporting plan that describes the scope of the project, including what is to be done, by whom and the timeframes.

**Action 1:** Assess readiness and prepare for change → **Action 2:** Project scoping and strategy → **Action 3:** Develop a project plan

## Action 1: Assess readiness and prepare for change

Before embarking on CCM, an organisation should know if it is ready and has the required understanding to properly scope the approach. It also should know whether it has, or can access the skills, knowledge and resources to implement CCM to a high standard. The most important ingredient is to have buy-in from senior leaders.

### Assessing readiness to adopt CCM

This Guide includes two tools that can help an organisation assess its current maturity, readiness and plan the approach. These tools can be used by an organisation whether they are embarking on CCM for the first time or looking to strengthen their existing approach.

### Planning and Readiness Self-Assessment Tool (Appendix C)

A series of questions to help an organisation determine their readiness and identify key items to consider in planning for commencing or strengthening CCM.

### CCM Maturity Model (Appendix D)

The tool is intended to help an organisation assess its current maturity in terms of CCM. It is structured as a journey chart, with each step describing an increased level of control management maturity. A higher maturity score suggests a higher foundation and level of capability to implement CCM. The assessment can be used to help an organisation develop their strategy and plan to commence the process or strengthen their current approach.

### Preparing for change

A sense of unease and uncertainty is common in organisations undergoing change. The adoption of the CCM process may challenge existing processes and routines, propagating these feelings. If the benefit of the change can be clearly communicated, it can help address the unease and uncertainty. Consider sharing experiences of the successful application of the control-focused approach from other organisations in the mining and metals industry, or from other high-hazard industries.

## Action 2: Project scoping and strategy

The first task is to define the project scope, which will help establish the goal, boundaries, and expected outcomes of completing the CCM process. It is important to tailor the scope for your organisation. The following questions may assist in making strategic decisions:

- what is the driver for implementing CCM? That is, why has the organisation decided to go down this path?
- what is the goal CCM is ultimately aiming to achieve? What does the successful endpoint look like?
- what types of events is the process aiming to prevent? What are the criteria or 'severity threshold' that would trigger an event to be included within CCM? (This is used in Step 2.)
- what is the organisational context that will influence the approach? Are there existing projects or changes that may complement or conflict with this work?
- are there any legislative or other external requirements that will influence the scope and approach?
- what parts of the business are expected to be included or excluded?
- how will the governance for the project work, both to endorse the approach and project plan and to provide ongoing oversight?
- what is the preferred delivery approach (model)? This could range from deploying across the whole organisation at once, or a region at a time, or starting with a pilot site.
- what is the approximate and realistic timeframe for major project milestones?
- are there any key decisions relating to integration with other HSE, risk or assurance systems or enterprise technologies that may impact the project?

**Scoping the hazards**

A key decision when scoping CCM is defining the criteria for deciding which hazards and unwanted events are included in the process. Organisations usually do this by setting a severity threshold – the level at which an event could have a significant and potentially material impact and therefore requires the highest level of rigour and attention. These criteria will differ between organisations.

It is recommended that the criteria are based more on the potential health and safety consequences of an event rather than its likelihood. The question is whether the event could happen and how severe the outcome could be, not how likely it is to occur. Perceptions of likelihood can be unreliable, especially for low-probability events.

The assessment should be based on the maximum reasonable consequence of the event, assuming the controls could credibly fail.

Events that do not meet the criteria are managed through the organisation's other risk processes and should be reviewed periodically. It is common for events initially excluded from CCM to be added later as circumstances change.

**Note:** Organisations may use various terms to describe the unwanted events included in CCM Common terms include, but are not limited to, critical risk, fatal risk, major hazard, principal hazard and catastrophic hazard. Definitions may vary between organisations.

## Action 3: Develop a project plan

The final action in Step 1 is to convert the intent into action, by developing a project plan. Implementing CCM is potentially resource-intensive, so ensuring that adequate resources are available is essential to the success of the project. The project plan will provide clarity on the actions, resources and timeframes to achieve the expected outcomes. The project plan should consider:

- project scope, goal and boundaries (defined in Action 2),
- specific project objectives – ensuring they are clear and reasonable for the timeframes,
- project governance structure,
- key roles and responsibilities,
- key project steps and actions,
- timeline for the project steps and actions,
- finance needed to support the project, and a mechanism to track spending,
- plan to communicate the project through available channels to the different audiences,
- plan to develop and implement an education/training package for the variety of roles involved in CCM implementation,
- human resourcing requirements, such as who and how many people are involved at each stage of the project:
  - a dedicated project manager from startup through to completion
  - an internal project team with at least some members dedicated full time to the project – the size of the team will differ between organisations
  - subject-matter experts for technical matters and advice – some organisations will have internal expertise; however, others may require external expertise
  - for multi-site implementation, consider allocating personnel who are dedicated to CCM full time.

### ECM's approach to project planning

Because of the significance of the project, the CEO asked the COO to sponsor and oversee the work. The COO then seconded an influential and well-respected operational leader to co-lead the project alongside the HSE manager. This partnership was designed to demonstrate that the CCM refresh would be operationally led, with functional support from HSE, building on learnings from the earlier implementation.

The CCM lead and HSE manager assembled a working group made up of a cross section of operational and support personnel. The working group's first task was to define the scope, goal and objectives for the refresh project. Benefits for the project were articulated. The working group decided to first refresh the CCM across the new underground business unit, before applying it to the wider company. The aim was to quickly implement CCM and to draw learnings before implementing to the rest of the business.

Follow along with the next learning example

# **Step 2:** Identify Fatal Hazards and Unwanted Events

**Target Outcome:** Identify and summarise the fatal hazards and unwanted events to be managed.

**Action 1:** Identify all potential hazards and unwanted events → **Action 2:** Select the fatal hazards and unwanted events for the process → **Action 3:** Assess opportunities to reduce exposure through design → **Action 4:** Describe the fatal hazards and unwanted events

## Action 1: Identify all potential hazards and unwanted events

This first action involves identifying an initial list of potential hazards and unwanted events to be considered for inclusion within the CCM process. In conducting this action, it is important to consider:

- the range of operational areas, processes and activities within scope,
- involving suitably experienced personnel to gain different perspectives, in particular those who best understand and are potentially exposed to the hazards,
- reviewing internal documents, such as existing hazard and risk assessments (they have often already been identified but for a different purpose),
- analysis of historical incidents within the organisation,
- consideration of any specific legislative or other external requirements,
- reviewing the wider industry context for historical and foreseeable future events – consider reviewing global mining incident data and publications for relevant hazards and events, including peer organisations that may have similar exposures,

— discussing different types of hazards and events separately (e.g. underground events may need to be considered separately to above-ground events, as the nature of the hazard, scale of potential consequence and control strategies may be different, e.g. fire on surface versus fire underground), and

— making the hazards and events specific to your organisation, applicable to either individual or multiple sites.

An example list of typical mining and metals hazards and unwanted events is included in Appendix E.

### What were ECM's criteria to select the hazards and events in scope?

The COO emphasised that the refresh and expansion of CCM into the underground business was a great opportunity for them to revisit and reset the scoping criteria for selecting which hazards and unwanted events should be included in the CCM process.

The group agreed to define a severity threshold at which an unwanted event would be deemed to warrant inclusion in the CCM process.

They discussed the different types of events, ranging from events with the potential for multiple fatalities or mass casualties, like the event that occurred at the Upper Big Branch Mine, along with the potential for individual fatalities from events associated with everyday work.

After discussion between the working group members, they landed on a threshold for both health and safety to be presented for endorsement by the executive and board:

— **Safety** – hazards with the potential for fatality, both individual and multiple fatalities. Examples included 'fall of ground' and task-related hazards such as 'working from elevated work platforms'.

— **Health** – hazards with the potential for life-altering impairment or death arising from acute or chronic exposures above the occupational exposure level. An example of this is diesel particulate matter (DPM) overexposure.

Follow along with the next learning example

## Action 2: Select the fatal hazards and unwanted events for the process

The next action is to review the initial list of hazards and unwanted events to determine those to be taken forward and included in the CCM process. This action involves comparing the events against the agreed scoping criteria and 'severity threshold'.

## Action 3: Assess opportunities to reduce exposure through design

This step provides the organisation an opportunity to re-evaluate opportunities to reduce the inherent potential of the hazard or the impact of the potential consequences, and thus potentially removing it from the CCM process. For example, substituting a hazardous product, automating a process, or relocating a hazardous process.

## Action 4: Describe the fatal hazards and unwanted events

Summarise the information for each fatal hazard and unwanted event to provide context for others to understand it. Documenting the description of each hazard and event should include the risk owner and other personnel that understand the risk and the CCM process. At a minimum the description should consider:

- a description of the fatal hazard, the event, mechanism of release and any specific scenarios,
- the background and importance of the fatal hazard – this provides context of where it exists,
- the scope and boundary of the hazard and events – this is a description of any events and areas that are considered to be included or excluded, and
- the potential health and safety consequences (may include capturing other significant impacts on the organisation).

### ECM learning example: Fatal hazard and unwanted event description

**Fatal hazard:** Geotechnical instability
**Unwanted event:** Underground fall of ground

**Event description**
Movement of ground beyond design tolerance, with potential for a localised rockfall or major ground collapse.

**Background**
Ground instability is a hazard within underground mining and 'fall of ground' is a known event with the potential to result in a localised rock fall with potential to result in permanent disabilities and fatalities due to rocks striking personnel, through to multiple fatalities from cases where there is larger rock mass failure and ground subsidence. In these cases, there is also the potential for a secondary impact from air blasts from the falling ground pushing air into drives.
Other consequences of these events include financial losses from equipment damage, recovery, litigation or process shutdown.

**Scope**
This hazard exists in any underground environment, whether in development or production phase. It may also exist in other underground excavations, such as reclaim tunnels. The nature of exposure is dependent on the mining and access methods.

**Boundary**
All underground activities that support underground operations.

**Potential consequences**
Immediate fatalities from the event. Secondary consequences such as mine fires due to liberated dusts will be treated as a separate hazard. Longer-term consequences may include lost production, processing delays or shutdown.

Follow along with the next learning example

# Step 3: Identify Controls

**Target Outcome:** Identify the controls for each unwanted event.

**Action 1:** Identify controls using the definition → **Action 2:** Sort controls from supporting activities

## Action 1: Identify controls using definition

The action to identify controls is a fundamental step in the process, as it lays the foundation from which the critical controls will be selected.

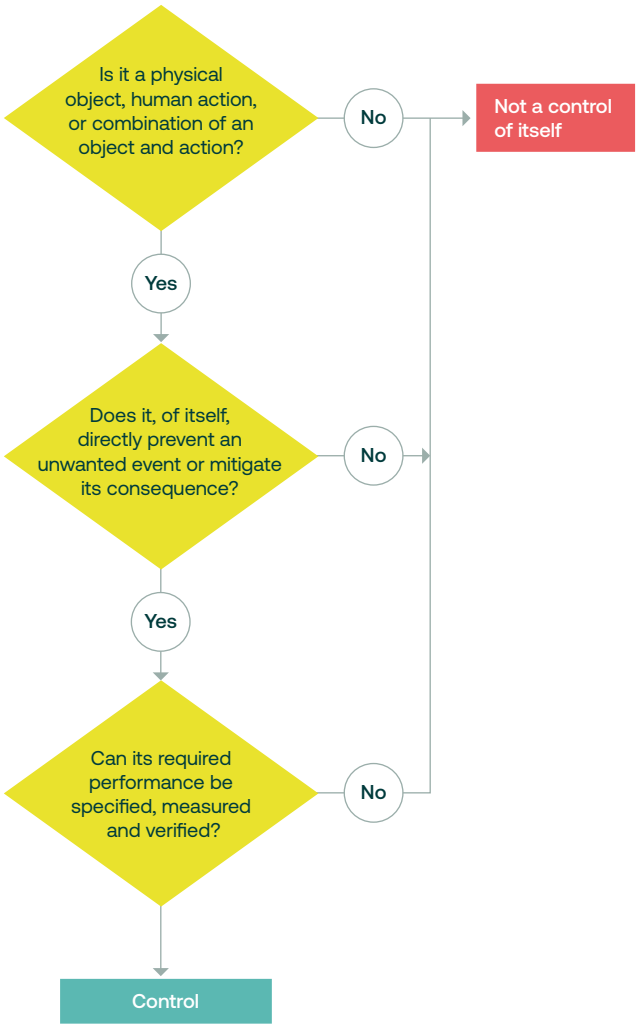
### What is a control?

Use the decision tree (see Figure 3) and following questions to help decide what is or is not a control:

- Is it an object, human action or the combination of an object and action (system)? (see Table 3)
- Does it, of itself, directly prevent an unwanted event or mitigate its consequences?
- Can its required performance be specified?
- Can its performance be measured and verified?

A **control** is a physical object, human action or the combination of an object and action that, of itself, directly prevents an unwanted event or mitigate its consequence. Its performance can be specified, measured and verified.

Figure 3: Control Identification Decision Tree




**Source:** Adapted from Hassall, M, Joy, J, Doran, C and Punch, M (2015).

Table 3. Summary of Control Types and Examples

| Control type | Description | Example controls |
|---|---|---|
| **Object** | A physical object (e.g. device or equipment) designed to prevent an event or mitigate its consequence. An object works without a human action, apart from a person's role in its design, installation and maintenance. | — Fixed handrails along edge<br>— Automated fire detection and suppression<br>— Height limited equipment used under energised power lines |
| **Human action** | An intentional human act, or what a person does (or does not do) to prevent an event or mitigate its consequence. | — Person maintains standoff distance from open edge<br>— Occupants evacuate to muster point<br>— Person maintains minimum clearance distance between plant and power line |
| **Combination of object and action** | The combination of an object and a human action. That is, the object will not function when needed without a human action. | — Person applies fall restraint (harness/lanyard connected to approved anchor point)<br>— Person activates fire deluge system<br>— Isolation of energised power line to allow for safe access |

### How to identify controls?

The identification of controls will typically involve the review of existing documents and/or applying a structured hazard analysis and control identification methodology. It is essential this action involves those personnel most knowledgeable in the hazards and people who routinely use and rely on the controls in practice.

### Review of documentation:

In most cases, the controls will have already been identified within existing documents or external references. The first step is to review these documents, for example:

— internal risk assessments and bowtie analysis,

— hazard management plans,

— internal operating and maintenance procedures,

— legislation that may contain general control advice or have guidance containing controls. In this case, controls should not be simply copied as they need to be assessed for relevance, and

— risk assessments from associated organisations or similar industries.

A **bowtie analysis** is a structured method used to understand how a fatal hazard can lead to an unwanted event, the controls required to prevent that event, and the controls needed to mitigate its consequences if it occurs. It visually links the hazard, the unwanted event and all associated controls, allowing organisations to identify which controls are critical and how they must perform.

### Hazard analysis and control identification methodologies

In choosing a hazard analysis and control identification methodology, it is important that the selected method suits the nature of the hazard and events to be assessed. The most common method applied in CCM is bowtie analysis, but there may be other methods that are equally suitable depending on the type of hazard. These methods may be used instead of or in combination with a bowtie analysis. For example, process safety hazards may require a Hazard and Operability study (HAZOP) and/or semi-quantitative tools such as Layer of Protection Analysis (LOPA).

Most methodologies, including bowtie analysis, will generate information on:

— what are the possible causes (or threats) that could lead to the unwanted event

— what preventative controls are in place (or could be put in place) to prevent these causes from leading to the event

— what controls are in place (or could be put in place) to mitigate that outcome or severity of the consequence(s)

The methodologies will also often help to understand the maximum reasonable consequences from the event.

**Table 4. Summary of Example Controls Against Unwanted Event, Causes and Outcomes**

| Cause | Prevention control | Unwanted event | Mitigation control | Outcome |
|---|---|---|---|---|
| **Weak or deteriorating ground conditions** | *Ground support (Object)* | Fall of ground – Ground movement beyond design tolerances | *Engineered operator protection devices (Object)* | Rock fall striking worker(s) resulting in single or multiple fatalities |
| **Overhead obstructions** | *Operator maintains separation distance from obstacle (Combination)* | Uncontrolled movement of elevated work platform in proximity to overhead obstruction | *Emergency shutdown in basket (Combination)* | Operator trapped/ crushed resulting in fatality |
| **Engine generating DPM** | *Low emission/alternative fuel options (Object)* | DPM release into the UG workplace (occupiable environment) exceeding OEL | *Enclosed cabins with high-efficiency particulate air (HEPA) filters (Object)* | Excessive worker exposure to DPM (above OEL) |

### Bowtie analysis

Bowties are a popular method to illustrate the linkages between the potential causes and outcomes of an event (see Figure 4). They help stakeholders, most importantly the frontline, to 'see' the layers of controls that are relied upon to prevent the event or mitigate the outcomes.

There is no one right way to develop a bowtie. However, they should be prepared by careful reference to the definitions in this Guide (see example bowtie in the learning example).

Proprietary tools are available, but bowties can also be drawn by hand (e.g. on a whiteboard) or developed with standard software.

Once the bowtie (or other method) is developed, it should be reviewed to:

— re-confirm the controls meet the definition and are not supporting activities (see Action 2),

— confirm that the controls are appropriate and relevant for each cause and/or outcome,

— confirm there are both preventative and mitigative controls, which provide control at different times with the event sequence (defence in depth),

— identify any causes/outcomes without controls, and

— assess the controls in consideration of their type and hierarchy – is there overdependence on human action/people-dependent controls over object/ engineering controls, which are typically more reliable.

**Understanding how controls can fail**

At this stage it may also be useful to identify and discuss any key erosion factors relating to specific controls. Erosion factors are the ways a control can degrade, be defeated or completely fail. They are also often referred to as degradation or escalation factors.

Understanding the erosion factors can be helpful in the subsequent step of determining which controls are more reliable and could be selected as critical (Step 4). It also helps with identifying support and verification activities for critical controls (Step 5).

To identify erosion factors, it is helpful to ask the following simple questions:

— What can cause the control to not work?
— How has the control failed previously?
— What changes could impact the control?

Examples of how human action controls can fail may include:

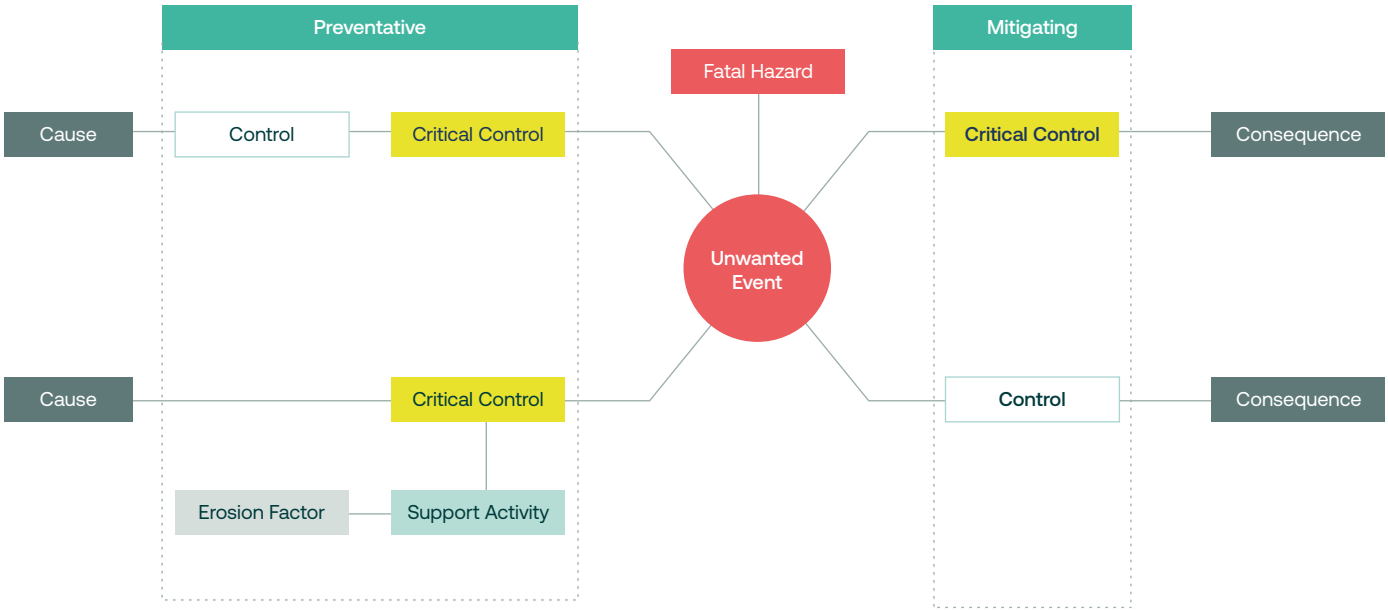
— Human error factors (workload, distractions, etc.)
— Inadequate procedures/work instructions
— Desensitisation (to alarms, signs etc.)
— Inadequate competencies and skills

Examples of how object and engineered controls can fail may include:

— Inadequate design
— Damage or defect
— Wear/corrosion
— Loss of service (e.g. power)

Controls that are a combination of human actions and objects share erosion factors with both categories.

**Figure 4: Simplified Bowtie Diagram**



## Action 2: Sort controls from supporting activities

An important action is to sort the true controls from their supporting activities. These are the various activities, processes and sources of information that support or enable the controls to perform as expected. They are important but are not controls in and of themselves, as they do not directly prevent the event or mitigate the consequence. Examples of support activities may include:

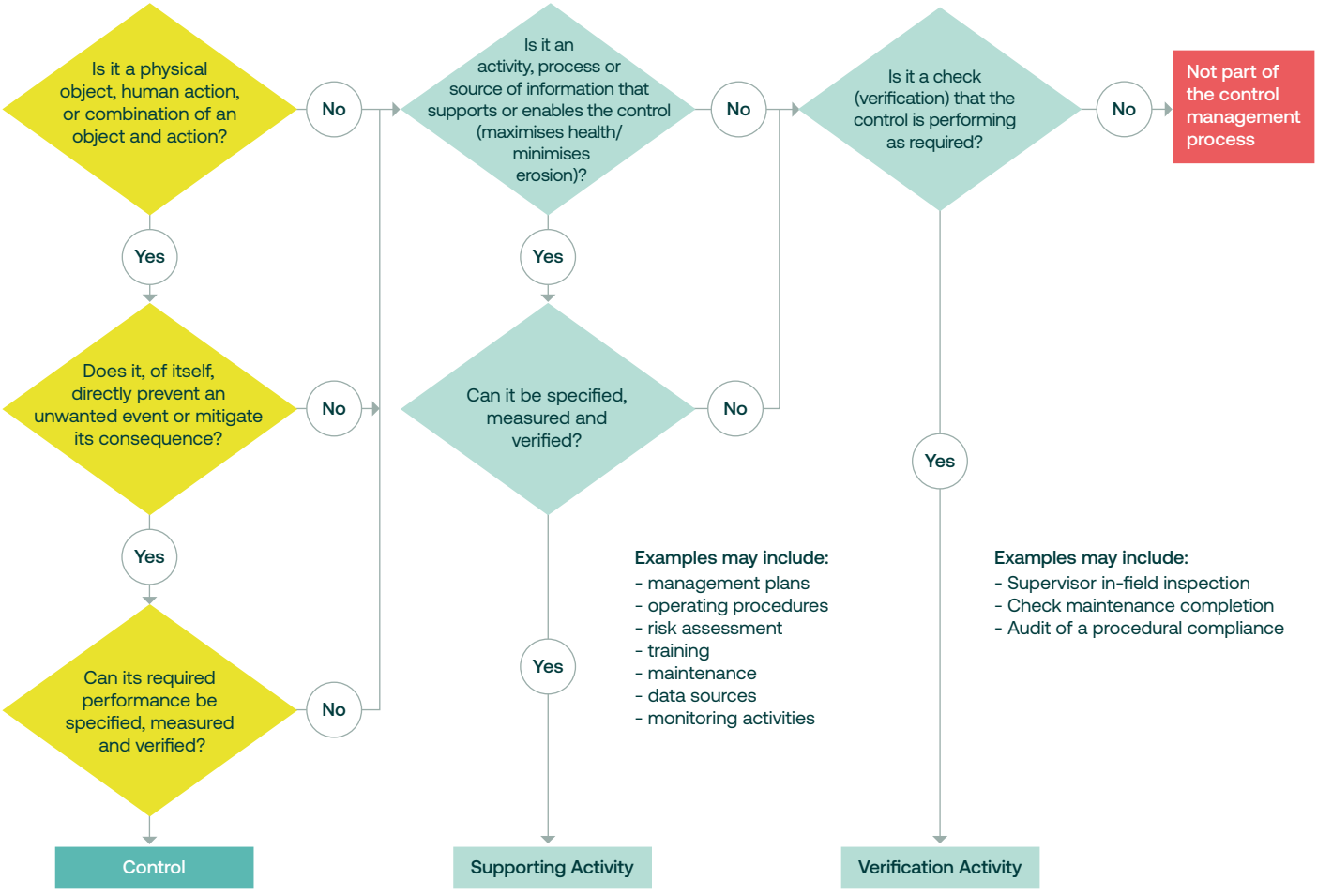
— management plans
— operating procedures
— risk assessment
— training
— maintenance
— data sources
— monitoring activities

Other commonly used terms for support activities are control supports, erosion controls, or supporting systems.

**Supporting activities** – The activities, processes and sources of information that support or enable the control to perform as expected. They maximise health/minimise erosion of the control.

For example, a management plan might describe controls, operating procedures may define the actions to be taken, risk-assessment techniques might lead to controls, training may lead to a person being competent in an action, maintenance may help prevent a control eroding.

**Figure 5: Controls Versus Support and Verification Activities**




**Source:** Adapted from Hassall & Harris (2017)

## How did ECM identify controls?

The ECM working group undertook to identify the controls needed to manage each of the fatal hazards and unwanted events for the underground business unit. This included both hazards and events that ECM had previously identified along with those that are unique to the underground operations.

This was done in two steps for each fatal hazard. It started with gathering and reviewing relevant documents and then used this information in a series of workshops with a cross section of personnel who were knowledgeable in the specific hazard and events.

For the 'underground fall of ground' event, the working group consulted with internal geotechnical, safety and operational personnel. For the activity of 'working from elevated work platforms' they primarily consulted with the frontline workforce who plan and execute the work. For 'DPM overexposure', they consulted with the vehicle's manufacturer, occupational hygienist, the vehicle maintenance team and the ventilation officer.

The causes and outcomes of each unwanted event were identified along with all the controls that could be implemented to prevent and mitigate the events. The working group initially identified a very large number of 'controls' that were able to be refined by asking the questions from the control identification decision tree in the 2026 Guide (see Figure 6).

This step revealed that several of the initially identified controls were in fact support and verification activities, rather than controls themselves. The group felt it was very important to capture these items as they are essential elements to maintain the health of the controls and will input into Step 5 to define the Critical Control Performance Specifications or Standard.

On this occasion the group decided to develop a bowtie diagram as it seemed appropriate for the hazard and the use of bowties was familiar in the organisation, noting there is no specific expectation in the CCM to use bowties. The bowtie for fall of ground is Figure 6 and for DPM is included in Appendix E.

These are the questions they used:

**Is it described as an activity, process or source of information that supports or enables a control, rather than directly managing the event itself?**
For example, the maintenance management system was often referred to as a control. Maintenance is not a control; it is a support activity that improves the likelihood that the control will function as required when needed. Applying this question led to a productive discussion that focused on identifying the object (e.g. equipment) that directly prevents the event or mitigates its consequence.

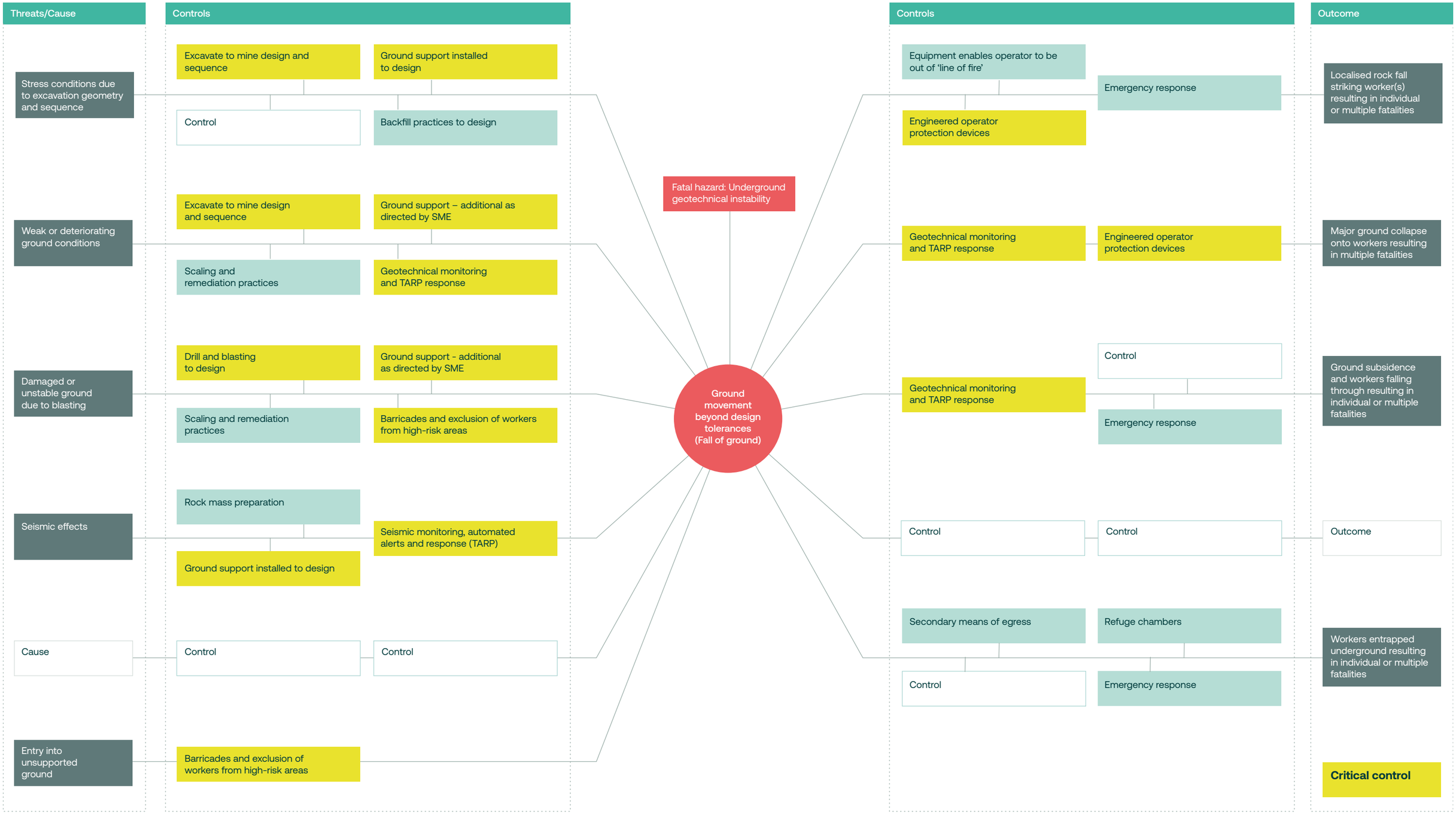
**Is it described as a plan?**
Hazard management plans were often identified as a control. They may have specific aspects that have previously been regarded as a control but are too general to be described as a control. The management plan does not solely control the source of harm or mitigate the consequence.

**Is it training or competence?**
Training and competence were not included as a control. It is of course important and often a legal requirement, but it is a support activity not the control. The control is the person performing the task to the required specification. Training imparts this knowledge to the person and as such it is a source of information the person uses to effectively implement the control.

**Is it described as a checking, inspection, quality assurance, or active monitoring activity?**
These are typically verification activities rather than controls. For example, if it is inspection of a pressure relief valve, the control is the valve not the inspection activity. The inspection confirms that the control is able to function when needed and play its role in controlling the hazard.

Follow along with the next learning example

## Figure 6: Underground Fall of Ground Bowtie



# Step 4: Select the Critical Controls

**Target Outcome:** Select the critical controls for each unwanted event. Summarise key critical control information.

**Action 1:** Select critical controls using criteria → **Action 2:** Summarise the critical controls for each fatal hazard

## Action 1: Select critical controls using criteria

Selecting the critical controls involves assessing all the controls for each fatal hazard and unwanted event to identify those that are deemed to be critical. In selecting the critical controls, it is necessary to consider both:

- how **reliant** the organisation is on the control to manage the unwanted event, and
- how **reliable** (dependable) the control is to prevent the event or mitigate the consequences.

The aim being to select controls that are sufficiently robust to justify being defined as critical and warrant the additional focus and rigour to verify their effectiveness.

Where bowtie analysis has been conducted, it is an excellent tool to help identify the critical controls, as it helps to visualise the role the control plays in managing the unwanted event.

As per prior steps, this step should include those people who are most knowledgeable in the fatal hazard and how the controls are applied in practice.

## Action 2: Summarise the critical controls for each fatal hazard

Collate a list of the critical controls for each unwanted event to be taken forward in the CCM process. Summarise the key information for each critical control including a refined title and which fatal hazard and unwanted event it relates to.

The following definition and criteria should be used to guide the selection of critical controls.

A **critical control** is a control for a fatal hazard that is crucial to directly preventing an unwanted event or mitigating the consequences of the event. The absence or failure of a critical control would significantly increase the likelihood of the event or the severity of the consequence despite the existence of the other controls.

The aim is to select controls that are sufficiently robust to justify being categorised as critical. The following criteria can be used to help select the critical controls (NB: Not all critical controls will meet all criteria):

- It is the **only control or heavily relied upon** to directly prevent an event or reduce the severity of the consequence (for an individual or across multiple events).
- It is reliable and **consistently functions** as intended under the range of expected conditions.
- It is more **reliable** (dependable) than other available controls. For example, preference for controls that do not rely heavily on human actions.

Additional questions to test for higher reliability:

- It is **independent** of all other controls and will still function if other failures occur.
- It will continue to function even when there is **human error** (unrelated to the installation or set up of the control).

**Note:** There should be evidence to show the presence (or failure) of the critical control is significant in managing the unwanted event.

## How did ECM decide what controls were critical?

The ECM working group started the work to assess the controls to determine which controls they deemed to be critical for recommendation to the senior leaders to be included in the CCM process.

The group began by reviewing the bowtie for an 'underground fall of ground event'. During this review, several controls stood out as clearly critical because they were crucial for directly managing the fatal hazard and had a strong record of consistently working as intended. One example of this was the installation of the ground support as per the approved plan. They considered whether the absence of properly installed ground support would significantly increase the likelihood of a 'fall of ground' event. The group answered 'yes'. One of the operational leaders expressed that it was only effective where properly installed and there had been several issues at their site in this area. The consideration with regards to the reliability of the control then focused on the adequacy of the training of the installers (source of information), the maintenance of the ground support (support activity) and the workplace inspections and audits of the ground control (verifications).

Other controls were also discussed to assess whether they were crucial or not.

The discussions raised concerns about how reliable some controls were in practice, particularly those that relied heavily on people to set them up or use them correctly (for example, temporary barriers instead of permanent installations). Although the group preferred to avoid controls that depend on human action, they recognised that in some situations these types of controls could not be eliminated entirely. The group agreed to review these people-dependent controls in more depth to identify ways to strengthen their reliability. The HSE manager also noted that the CCM process would allow them to formally reassess the reliability of these controls using the outputs generated through the process.

Follow along with the next learning example

## What were ECM's critical controls for 'underground fall of ground'?

**Table 5: Critical Controls for 'Underground Fall of Ground'**

| Hazard/unwanted event | Example critical controls | Example support activities |
|---|---|---|
| **Underground geotechnical instability**<br><br>**Fall of ground underground: Movement of ground beyond design tolerance.**<br><br>Example scenarios:<br>— Localised rockfall or burst<br>— Major ground collapse | Excavate to mine design and sequence | — Excavation stability analysis for mine design<br>— Mine plan and approval process<br>— Survey control to confirm alignment to plan<br>— Reconciliation of actual extraction versus plan |
| | Ground support installed to design | — Ground support plan and approval process<br>— Ground support QA/QC testing |
| | Drill and blasting to design | — Drill pattern design<br>— Blasting plan and approval process |
| | Geotechnical monitoring and response as per TARP | — Maintenance and calibration of instruments<br>— Trigger Action Response Plan (TARP) |
| | Barriers and exclusion of workers from high-risk areas | — Mine hazard maps<br>— Barricading procedures |
| | Engineered operator protection devices | — Equipment specification<br>— Maintenance program |

# **Step 5:** Define Critical Control Performance

**Target Outcome:** Define and summarise the critical control objectives, performance requirements, and how they are to be supported and verified in practice.

**Action 1:** Define the critical control objective → **Action 2:** Define the critical control performance requirements → **Action 3:** Identify the support activities for the critical control → **Action 4:** Define verification or 'checking' activities

The outcome from this step will be for the information for each critical control to be summarised into a Critical Control Performance Specification or Standard. Refer to example on page 39 (Table 6).

## Action 1: Define the critical control objective

Defining the objective of the critical control will help with understanding the role of the control and the expected outcome it is aiming to achieve (its purpose). The critical control objective is a short plain language description of what the control is required to do. To help define a critical control's objective, consider:

— What is the outcome that the critical control is aiming to achieve?

— How will the critical control achieve this outcome?

For example, the objective of the control '*Energy Isolation*' could be: '*To prevent exposure to a fatal energy source by ensuring all energy sources are positively isolated, locked out, tagged out and verified as isolated*'.

## Action 2: Define the critical control performance requirements

The performance requirements are the standards or criteria to which the critical control has to perform to meet its objective (as defined in Action 1). The performance requirements are used by those who are responsible for implementing and verifying the controls. They therefore need to be written in a manner that ensures they are:

— **specific**: clearly defined and not vague,

— **measurable**: quantifiable and/or easily measured (verified) wherever possible, and

— **realistic**: achievable in the operating context.

As per identifying controls, the performance requirements may already exist within documents, such as hazard plans, procedures, design specifications and maintenance manuals. They may also be in industry codes and standards, but these need to be applied cautiously as may not be specific or relate directly to the context for an organisation.

There is no single way to approach the development of performance requirements, but it is essential to always involve those personnel who are most knowledgeable of the control and how it is applied in practice.

Common approaches to developing performance requirements are provided below. These approaches are often used in combination.

Developing performance requirements may be as simple as asking the following two questions about the design and implementation of the control:

— **Design:** What design characteristics does the control need to have to consistently work (function) as required?

— **Implementation:** What is required to ensure the control is available and will reliably work when needed?

A second technique is to start by listing the distinct elements that 'make up' the control and together enable the control to meet its objective – deliver overall functional performance. Example elements include:

— Objects/equipment (e.g. gas detector and alarm, or harness and fall arrest lanyard)

— Actions/task (e.g. operator responding to an alarm or attaching lanyard onto an anchor point)

An element on its own does not constitute a control – ie in the example above, an alarm on its own will not stop the event, as it depends on an operator response. Both elements come together to form the control.

Performance requirements that cover each of the control elements can then be prepared. This approach can also assist in identifying the supporting activities that are relevant to individual elements (e.g. inspection and testing of the gas detector). For example, for the control of 'energy isolation' this could include:

— Correct application of the isolation procedure by competent person,

— Isolation point identification and labelling,

— Suitable isolating device,

— Suitable locking device,

— Tagging or labelling to identify the authorised isolator and isolated person(s),

— The action to test and verify the isolation by competent person, and

— The action to reinstate the process.

A third common technique is to use prompt terms to help identify performance requirements. A common set of prompts is to think through what the control needs to achieve in terms of its functionality, availability and reliability.

— **Functionality:** How does the control need to function (operate) in order to meet its objective?

— **Availability:** What is required for the control to be available to perform its function, should it be needed? For example, ensuring it remains online and not bypassed, taken out of service or inhibited?

— **Reliability:** What is required to ensure that at any point in time the control will reliably function (operate) as intended? For example, ensuring it is function tested, inspected and maintained?

This method is particularly suitable for physical objects (e.g. equipment or devices) or system-based controls.

For controls that are reliant on human actions, a similar approach can be used to guide the development of requirements. The following list contains helpful questions to ask:

— What specific actions need to be performed?

— What is needed to ensure the action is completed correctly and within the required timeframe?

- Who performs the action?
- What information, tools or equipment is needed to perform the action successfully?
- What competency, knowledge or skills are necessary to perform the action successfully?
- Are there any formal authorities (e.g., permits, approvals) required to perform the required action?
- Is there a step to ensure the action was completed correctly (e.g. task sequence, hold point, peer cross-checks or sign-off)?
- How will personnel know whether the actions have been completed successfully?

**Defining the target performance**

The critical controls 'target performance' is a short summary of the performance requirements. It is primarily used in the design of the control and in the step to evaluate effectiveness (Step 9). The performance target should be specific and quantified where practical. For example, a pressure relief valve might have a target performance of 100 per cent on demand. A fire monitor intended to disperse a flammable or toxic release might be expected to operate on demand and deliver a specified flow of water for a specific time.

**Defining performance triggers**

The 'performance triggers' are the point at which the control performance may lead to an operation or specific activity being required to cease (or not start) and the critical control be rectified or be reviewed or investigated. This may require the situation to be escalated to more senior leadership and potential to involve relevant technical authority/subject-matter expert to help decide the best course of action in response to the situation.

Organisations may also define business rules for when a more formal critical control review is triggered, such as the result of repeat cases of a control not meeting its required performance ('amber' or 'reds') or incident(s) involving the absence or failure of the critical control.

### How did ECM define critical control performance?

The ECM working group decided the most effective way to complete this step was through a series of workshops that included those personnel who knew about the critical controls in practice, such as frontline supervisors and workers.

The objective of the workshop was to develop each critical control objective, performance requirements and how the control is to be verified in practice.

The group used the prompt questions to guide the conversation. They then summarised this information into the Critical Control Performance Specification. An example for the critical control of ground support is included in Table 6.

Follow along with the next learning example

## Action 3: Identify the support activities for effective critical control performance

The next step is to identify the 'support activities' for the critical control.

A **support activity** is an activity, process or source of information that supports or enables the control to perform as required.

Support activities typically align directly to one or more of the performance requirements. For example, if a performance requirement for isolation of energy is 'to ensure isolations are tested and verified', the support activity may be the competency-based training in the isolation process, which includes training on how to test and verify isolations. To identify support activities, it may be helpful to:

- review existing documents that relate to the control or activities where the control is used,

— speak with personnel that work closely with the controls, and

— review the **erosion factors** for the control, which may have been identified in Step 3.

Understanding how the control can erode helps to identify both the supporting activities along with the verification activity to check the control is performing as expected (it is not eroding). For example, if the erosion factor is corrosion and wear and tear, the support activity may be the corrosion protection programme and maintenance to schedule.

Support activities should be described in terms of how they specifically support or enable the critical control, rather than just referring to elements of the management system (e.g. risk assessment, contractor management, and change management). For instance, in the example above, the training was specific to 'isolation of energy procedure' versus referring to 'training and competency' more generally.

NB: Establishing and maintaining the link between the critical control's performance requirements, erosion factors, support activities and verification activities is fundamental to the process. The link can be shown in the performance specification and also on other documents, such as the bowtie. Visually showing this link can significantly help stakeholders make the connection between these important aspects of the process.

## Action 4: Define verification or 'checking' activities

The final action in Step 5 is to define the 'verification activities'. Verification activities need to be focused in order to provide an adequate understanding of control health.

Below is high-level guidance on identifying verification activities, with further guidance on how verification activities are completed in practice in Step 7.

A **verification activity** is the process of checking the extent to which the performance requirements set for a critical control, are being met in practice. This will usually involve the physical verification of the implementation of the critical control and on occasions verifying its design.

The model adopted for assigning accountabilities for verification activities will influence how they are defined. For example, there is a need to distinguish between the control implementation checks that may occur in the field by any leaders, including frontline personnel, versus activities that may involve reviewing a control's design and supporting activities. The latter being more suitable to be completed by control owners, other leaders and subject-matter experts (SMEs).

It can be useful to begin identifying the verification activities while reviewing the documents and speaking with personnel as part of the prior actions. In addition, consider the following questions:

— what checking is needed to verify the critical control meets its required performance?

— how does the control typically fail (erode), and therefore what needs to be checked?

— what type of checking is needed (ie does it require in-field observation and engagement with workers, or reviewing supporting activities),

— how frequently does the type of check need to occur (For example, a field check that occurs frequently or a design/systems check that occurs quarterly, six monthly or even annually?), and

— who is best to do it (see Step 6).

Organisations may choose to alter the frequency of verifications dependent on the nature of the critical control. For example, permanent engineered controls may require less frequent but more technical verifications, compared to human-dependent controls that are part of routine operations. Verification schedules should be designed to be realistic and achievable for the verification activity owners

The outcomes of the verification activities should be reported up the ownership chain on a regular basis. The reporting structure is defined in Step 6.

At the end of Step 5 the information can be compiled into a Critical Control Performance Specification. The template in Table 6 is a guide only and can be adapted to an organisation.

## Table 6. Sample 'Ground Support' Critical Control Performance Specification or Standard

| | | | | |
|---|---|---|---|---|
| **1. Related fatal hazard and unwanted event(s)** | Geotechnical – 'Fall of ground' underground | | **Risk owner** | **Underground mine manager** |
| **2. What is the name of the critical control?** | Ground support | | **Control owner** | **Mining Superintendent** |
| **3. What is its specific objective related to the unwanted event?** | Ground support is installed to maintain stable ground over the life of the excavation, so as to prevent ground failure, subsidence, or rock fall. | | **7. What are the activities to confirm the control is performing as required (verification activities)?** | |
| **4. What are the controls performance requirements to meet the objective (Performance Requirements)?** | **5. How could the control erode or be compromised (Erosion Factors)?** | **6. What are the activities, processes or sources of information that support or enable the control (Support Activities)?** | **Verification of design/support activities[1]** | **Verify implementation[2] (typically in-field)** |
| All active areas have ground support that is designed and documented within a Ground Support Plan, which meets industry accepted methodology appropriate for the failure modes and mechanisms identified at the site. | — Inadequate design – not to the specific conditions .<br>— Plan not prepared by a competent and qualified individual.<br>— Changes occur that affect design. | — Ground support designs are developed by a competent and qualified individual, following industry accepted methodology.<br>— Ground support designs are detailed in a Ground Support Plan that are to be controlled in the site document control system.<br>— Change management of significant changes impacting ground support design: e.g. changes to mine design and/or sequence, method, or rock mass conditions. | — Review to confirm all active mining areas have an approved Ground Support Plan, managed in the site document control system.<br>— Review that the ground support designs are developed by a competent and qualified individual.<br>— Check that management of change has been applied to any changes that may impact the ground support designs. | |
| Ground support is installed in all active areas as per the approved design in the Ground Support Plan. | — Incorrect installation.<br>— Inadequate stores of ground support materials. | — Ground support reconciliation to mine plan.<br>— Competency-based training of personnel installing the ground support.<br>— Stores have adequate supply of ground support materials. | — Check training records to confirm personnel installing ground support have current competency.<br>— Check support materials are adequately stored and rotated, with suitable quantity of supplies. | — Observe selected active areas to confirm the ground support is installed as per the approved Ground Support Plan. |
| Installed ground support is correctly installed and in functioning/working condition – inspected, tested and maintained to meet specifications. | — Damage due to machinery interaction.<br>— Environmental factors such as corrosive groundwater conditions (requires protection of ground support via galvanisation and/or encapsulation).<br>— QA/QC process is not in place or not clear.<br>— Inspections and tests are not to quality or schedule.<br>— Defects not identified or not rectified. | — Ground Support QA/QC programme is documented in a Procedure.<br>— QA/QC testing by supplier/3rd party in accordance with recognised standards to verify support elements delivered to site.<br>— Field measurements and tests of installed ground support (e.g. bolt hole length and extent of encapsulation, bolt pull tests, shotcrete thickness).<br>— Ground awareness training for frontline workers, to assist them to identify and notify of defects and unexpected ground movements/conditions. | — Check that the ground support QA/QC programme is documented in an approved procedure.<br>— Review records to verify that ground support QA and QC including testing, field observation and measurement is being undertaken to the approved procedure and frequencies.<br>— Check that any QA/QC non-conformances have been reported and actioned. | — Check for visual defects in installed ground support (e.g. bolt type, spacing and tail length, type of mesh and overlap length).<br>— Confirm understanding of frontline workers on conditions that would require notification (e.g. ground support defects of unexpected ground movement/ conditions). |

| **8. What is the target performance for the critical control?** | **9. What is the performance trigger for shutdown, critical control review or investigation?** |
|---|---|
| Ground support is installed in all active areas, as per an approved plan, prior to entry.<br><br>Ground support QA and QC tests and field checks are undertaken in accordance with the procedure and not exceeding + 1 month of the specified frequency.<br><br>> 95% compliance achieved against all QA and QC tests/checks and an action plan is established to address non-conformances. | **Go/No Go triggers:**<br>— Ground support is not installed to plan<br>— Visual defects in ground support<br><br>**Control review triggers:**<br>— Repeat gaps identified through verifications or failing to meet target performance<br>— Significant actual or potential incident relating to ground support being absent or ineffective. |

1. Typically a 'system' based verifications completed by nominated personnel (eg risk and control owners, operational leaders and specialists) at nominated frequencies (eg quarterly, six monthly, annually).
2. Typically an 'in-field' verification that typically occur more frequently based on risk/exposure by nominated personnel, operational leaders and workforce.

# Step 6: Assign Accountability

**Target Outcome:** Assign accountability and ownership for each fatal hazard, critical control and the verification activities.

**Action 1:**
Assign ownership and accountabilities

## Action 1: Assign ownership and accountabilities

A key benefit of CCM is clarifying the accountabilities and ownership for each fatal hazard, critical control and the verification activities. The assignment of accountability and ownership also forms the basis of CCM governance through the line of reporting.

Identifying the appropriate positions or individuals to be the 'owners' will depend on the internal organisational structure, such as single or multi-site operations, and the tasks being assigned. It may even be the case, particularly in smaller operations, that the same position or individual fulfils more than one role (e.g. the risk owner is also the control owner and completes the verifications). In these cases, it is critical that there is also a level of independence built into the process. For example, other personnel also do verifications and quality, and assurance checks are conducted.

Figure 7 illustrates an example of the relationship between these roles and Table 7 summarises accountabilities.

Figure 7: A Sample CCM Accountability Framework

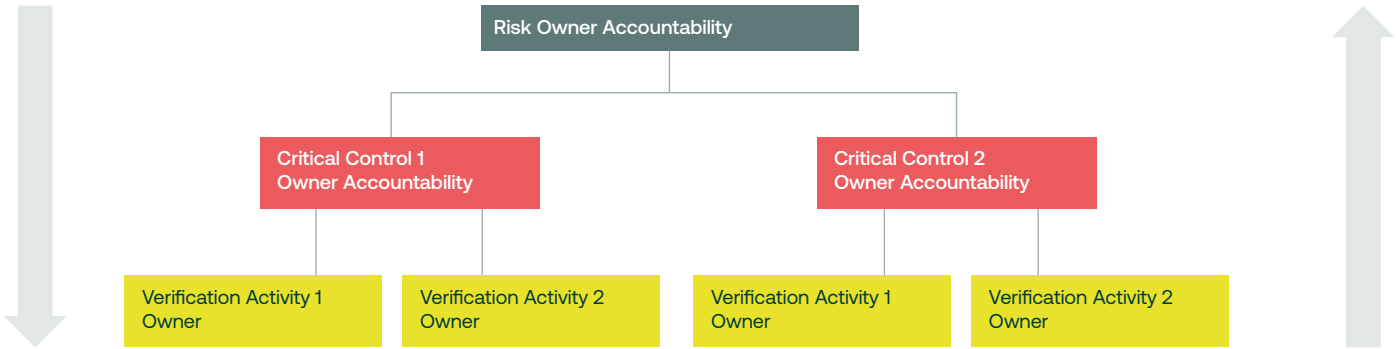


Table 7. Risk and Control Ownership Accountabilities and Actions

| Role | Example role level (Who) | Definition and accountability (What) | Action (How) |
|---|---|---|---|
| **Risk owner** | Senior leader or Operational leader | Provide oversight to confirm that the controls for managing the fatal hazard are well designed and implemented as intended. | — Undertake verifications or ensure they are completed.<br>— Monitor and review (e.g. monthly) reports on critical control health (effectiveness) and feed up to the leadership team.<br>— Conduct a periodic (e.g. six monthly/annual) review to formally evaluate the effectiveness of the critical controls to manage the fatal hazard (Step 9). |
| **Control owner** | Operational leaders | Ensure an individual critical control for managing a fatal hazard is adequately designed and effectively implemented.<br>NB: Where a critical control relates to multiple events it may have the same control owner (e.g. isolation of energy). | — Undertake verifications or ensure they are completed.<br>— Report on critical control health (effectiveness) to risk owner.<br>— Conduct a periodic review to formally evaluate the effectiveness of the individual critical control to manage the fatal hazard (Step 9). |
| **Verification activity owner** | Any assigned leader or SME | Conduct the assigned verification activity to check the extent to which the performance requirements set for a critical control are being met in practice. | — Undertake verifications or ensure they are completed.<br>— Report outcomes and escalate issues to the leader and/or control owner/risk owner. |

## Who should the 'owners' be?

The working group has a mixture of line leaders, technical subject-matter experts and HSE personnel. The initial view of most members was that HSE would be the owners of the fatal hazards, controls and responsible for carrying out the verification activities. The HSE representative strongly disagreed, reminding the group of the COO's direction that CCM must be owned and driven by operations, with HSE playing a supporting role – not the other way around.

The working group quickly agreed that it was the line leaders responsibility to implement the critical controls, but there was still disagreement about the verification activities. Some working group members believed that HSE should conduct the verifications because they already perform audits. However, verifications are part of line-leadership accountability.

The COO emphasised that an essential part of any line leader's role was to check (or verify) that tasks within their sphere of responsibility were being conducted as intended. This especially applied to critical controls.

HSE should not be expected to do the line manager's job for them. This was accepted by the working group.

## What is the role of HSE in CCM?

The question was raised as to what was the role of HSE if it was not to own and verify the controls? The HSE manager emphasised that their department would play a significant role in supporting operations as well as being the custodians of the process and regularly monitor and assess the quality of implementation.

Furthermore, because CCM dealt with the most significant hazards and events, internal audit would design an assurance programme on behalf of the company's audit and risk committee. HSE would work with internal audit to determine what was audited as part of that programme once the CCM process was implemented. This assurance programme is not covered by the CCM process.

Follow along with the next learning example

# Step 7: Critical Control Implementation

**Target Outcome:** Develop a plan to tailor the CCM content to meet local context and implement the critical controls.

**Action 1:** Tailor the CCM content to the site level → **Action 2:** Endorse site-level CCM materials → **Action 3:** Engage operational personnel in CCM implementation → **Action 4:** Implement critical controls

## Action 1: Tailor the CCM content to the site level

Where the development of the CCM content (Steps 2–6) was completed at a corporate or business unit level, it is essential that it is reviewed by site personnel before commencing implementation on a specific site. This step of 'localising' the content is needed to ensure the content is tailored to any site-specific context or requirements and is clear for each of the roles who is responsible for implementing and verifying these critical controls at site. Once this action is complete, the materials are ready for site deployment.

It is critical that this step is approached through framing the question as: 'how do we make this work at our site and our context?' and not conducting a wholesale review of the content. The content was developed through a systematic process involving experienced people.

It is essential that the localising of content includes engaging with site-based personnel that work in the areas relevant to the fatal hazards. This may include operational leaders, frontline leaders and team members (employee/contractors). Feedback from the roles at the different levels of the organisation will significantly assist to ensure 'buy-in' and ensure the process is implementable onsite. The learning example includes an example of how this can be done.

### How did ECM tailor the CCM approach for a specific site?

The next step was to take the information developed at the business unit level and implement it at each of the two underground mines and shared processing facility.

The sites were motivated to do so, particularly for the underground hazards. The mine had recently opened their deepest production level and there were concerns about the increased seismic stress and related geotechnical issues, so the risk of 'fall of ground' was front of mind to the workforce. The ventilation system is also at its maximum capacity increasing the concentration of diesel particulate matter on some levels.

A site-specific working group, including selected members of the ECM CCM project team and operations, set about reviewing the existing material to confirm their suitability and application at each site. The specific documents reviewed are listed in Table 8 below.

Follow along with the next learning example

Table 8. Tailoring Content to Site

| Step | Items reviewed and tailored to site level |
|---|---|
| Step 2:<br>Identify fatal hazards and unwanted events | Review of the descriptions for each fatal hazard to confirm it is relevant and matches site context. |
| Step 3:<br>Identify controls | Review of the bowtie diagrams and other materials used to identify the controls for each fatal hazard and event. |
| Step 4:<br>Select the critical controls | Review of the critical controls to ensure they are relevant and appropriate for the site-specific context. |
| Step 5:<br>Define critical control performance | Review and tailor the Critical Control Performance Specifications or Standard considering the site-specific requirements for the:<br>— control objectives<br>— performance requirements<br>— activities that support critical control performance<br>— activities to verify performance (verification activities)<br>— frequency of verifications<br>— reporting requirements |
| Step 6:<br>Assign accountability | Review and tailor the assigned 'owners' and the lines of reporting to match the roles at the site level. |

## Action 2: Endorse the site-level CCM materials

The documents tailored in Action 1 should be reviewed by the CCM Lead at the corporate level. This ensures consistency in the application of the CCM process between sites. Sites should adjust the material as necessary based on feedback. Significant changes from corporate-level materials may require an exemption process to be followed.

### How did ECM maintain governance over the site changes?

An important question raised by one of the site team was if site personnel questioned whether a control was appropriate for their context, what formal process they should follow to review or escalate this. Not escalating site personnel concerns to senior management risks weakening ECM's oversight of fatal hazards.

As a result, it was agreed that any significant changes proposed at site level to the material developed by ECM in the earlier steps will be formally signed off using the company's management of change system.

Follow along with the next learning example

## Action 3: Engage operational personnel in CCM implementation

A fundamental aspect of CCM is the focus on ensuring the critical controls are effectively implemented in practice. A key action to achieving this is to engage and align the operational personnel on the CCM process expectations. This can be done through running onboarding sessions to both engage with the frontline workforce and to seek feedback on any issues or concerns, such as potential challenges or barriers to critical control implementation and verification. An onboarding session may cover items such as:

- What is CCM and why is it important?
- What are the fatal hazards, unwanted events and associated critical controls?
- What are the performance requirements for the critical controls?
- What are the support activities and verifications to be conducted and who is accountable?
- What are the critical control performance targets and triggers, particularly the 'Go/No Go' criteria?
- Who to escalate issues to around critical controls?

## Action 4: Implementation of critical controls

The final action in this step is to implement the critical controls as per the defined requirements. The scope of CCM means there may be a wide variety of critical controls, ranging from those that are inherently in place as part of the process through to those which require workers to put them in place each time the task being undertaken (e.g. working at heights, conducting a lift or operating mobile equipment).

An example of the first type of control would be an engineering control, such as a permanent fixed guardrail, and the second being the installation of a temporary barrier for a specific task. Importantly, all controls require some degree of human involvement, even if to just inspect, maintain and verify its integrity over time. Hence the focus in this guidance on the importance of everyone being engaged and clear on their role in the process.

### How did ECM go about engaging the workforce?

At this point, most of those involved believed the work to tailor the content was largely complete. However, they were then asked to go into the field and talk to the frontline who had responsibility for implementing and/or verifying the critical controls – mainly frontline operators and supervisors. Their task was to ask the frontline personnel to identify inaccuracies, omissions and improvements. They were also asked to praise feedback – even if they disagreed with it. However, there was scepticism that this action would be useful, as they had already done the tailoring.

The following day they were asked to report on what happened. They reported that several of the documents needed amending based on what was found in the field and several managers reported that they received other suggestions and ideas to make the frontline work more efficient. All agreed this was a useful step.

This approach to defining critical controls proved successful in building a shared view (between management and frontline personnel) of the critical controls, their function and how to verify their effectiveness.

Follow along with the next learning example

**Connecting CCM to work management**

CCM is primarily about the process or 'system' for ensuring the critical controls are identified, defined, implemented and verified as in place and effective. With regards to the implementation of critical controls that need to be established on a task-by-task basis, the CCM process is reliant on the sites' planning and work management processes. This starts well before the day of the task, in the initial design and scheduling of the work. It then flows through the subsequent steps to ensure the frontline workers:

— Know the fatal hazards, unwanted events and critical controls related to their work – such as via discussions at pre-starts and pre-task hazard analysis,

— Have the capabilities, resources and sources of information required to implement the critical controls – such as through training and incorporating critical controls into procedures and work instructions,

— Are clear on the agreed 'Go/No Go' criteria, if a critical control is not in place or ineffective,

— Are provided with adequate direction and support from leaders, and

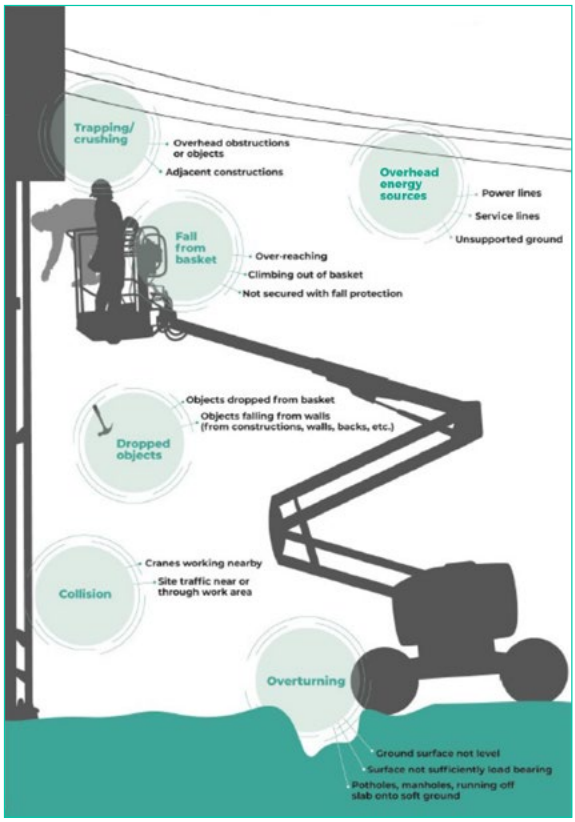
— Are able to identify and adapt to changes and variations in the task – while still achieving the requirements of the critical controls.

CCM then provides a means to periodically verify that the critical controls are being effectively applied. A description of the process to connect critical controls with the daily work management process is described in Appendix F.

## How did ECM use illustrations to engage the frontline workforce?

The use of mobile elevated platforms is a task that occurs every day across ECM and has significant fatality exposure. ECM chose to use illustrations as a way of engaging and communicating the critical controls to the frontline workforce and the other roles responsible for implementing or verifying the controls. This includes both ECM employees and a number of contractors who do this activity on their behalf. This approach was highly valued by the workers as it enabled them to see the controls in context.

Follow along with the next learning example




| Hazard | Controls | In place / working? |
|---|---|---|
| Trapping/ crushing | Secondary guarding or crush protection | ☐ |
| | Load limits in personnel basket (including personnel limit) | ☐ |
| | Ground supervision by standby person | ☐ |
| | Head protection (eg chin strap helmets) | ☐ |
| | Visual and radio contact | ☐ |
| | Emergency stop switch in basket | ☐ |
| Fall from basket | Full body harnesses for fall restraint or fall arrest | ☐ |
| | Fall protection with dual lanyards connected to anchor point | ☐ |
| | Anchor points and snap hooks inspected by competent person | ☐ |
| | Ground supervision by standby person | ☐ |
| | Visual and radio contact | ☐ |
| | Secure guard rails with self-locking gate | ☐ |
| Dropped objects | Signage and hard barricades to demarcate 'no go zone' | ☐ |
| | Tools stored securely in toolboxes and bags | ☐ |
| | Heavy tooling secured by lanyard | ☐ |
| | Only elevate necessary tools and equipment | ☐ |
| | Toe boards | ☐ |
| Overhead energy sources | Ground supervision by standby person | ☐ |
| | Isolation (electrical, mechanical or chemical) | ☐ |
| | Do not move with extended boom or with people in basket | ☐ |
| | Exclusion zone for overhead power lines | ☐ |
| Over-turning | Overload alarm or load limit switch | ☐ |
| | Ground condition and stability inspection | ☐ |
| | Limit propel function if tele-boom is swung past 90 degrees | ☐ |
| | Stability and slope alarm | ☐ |
| | Outriggers / stabilisers (if applicable) | ☐ |
| Collision | Approved and communicated travel and traffic plans | ☐ |
| | Visual and radio contact | ☐ |
| | Do not move with extended boom or basket in raised position | ☐ |
| | Signage and hard barricades to demarcate 'no go zone' | ☐ |
| | Ground supervision by standby person | ☐ |

# Step 8: Critical Control Verification

**Target Outcome:** Conduct verification activities and take corrective action when required.

**Action 1:** Conduct verification activities → **Action 2:** Act on verification outcomes

## Action 1: Conduct verification activities

Core to the CCM process is the action of conducting the verification activities as described in Step 5.

**What is a verification activity?**
A verification activity is a structured check carried out to confirm whether a critical control is in place and working as intended. It focuses on gathering evidence from the field, processes or people to understand the current state of the control. Verification is not an audit or a compliance exercise. Its purpose is to give leaders and teams timely, accurate insight into whether the control is effective in day-to-day operations, so that gaps can be identified and addressed before an unwanted event occurs.

**Who does verifications?**
It is the responsibility of the risk and control owners to ensure verifications are conducted on the critical controls. However, other roles will also conduct verifications, such as:

- Line leaders will carry out verifications as they are accountable for ensuring the critical controls are properly implemented in their areas of responsibility.
- Senior leaders should carry out some verifications as part of their leadership in-field activities.
- SMEs may be required if the critical control has technical elements or requires specialist knowledge, such as engineered and/or instrumented features, and
- Health and safety personnel to provide independent checks of the quality of verification activities.

The following Table 9 outlines a typical approach to the design of a verification regime.

## Action 2: Act on verification outcomes

The initial response to a verification will vary depending on the specific circumstances. Where gaps are found (e.g. 'amber or red'), this will include deciding on what immediate action to take, which may include:

- rectifying the critical control (closing the gap)
- reporting and/or escalating what was found, or
- in some circumstances ceasing or modifying the activity.

The outcomes also input into the wider assessment of the critical control effectiveness, as described in Step 9.

**Control Effectiveness**
A measure of the performance of the control(s) in managing the fatal hazard, considering the adequacy of its design and implementation (operating) effectiveness.

**How should leaders respond to outcomes?**
Where a critical control does not meet a performance requirement it is both a serious gap and an improvement opportunity. How leaders initially respond to a gap (an 'amber' or 'red') is critical to building trust and encouraging open reporting. This scenario is discussed further in the learning example.

Table 9. Typical Verification Approach

| Role | Who | Why |
|---|---|---|
| **Senior leaders*** | Executive and general managers | Visibly reinforce the importance of CCM and gain firsthand assurance on critical control implementation – 'trust but verify'. Typically conduct the same verification as the operational leaders. |
| **Operational leaders and specialists*** | Manager, superintendent subject-matter experts, functional leads | Check the control design, supporting activities and/or implementation meets the defined requirements. **Note:** It is important that this level periodically verifies the implementation of the control in practice, and does not solely rely on the results of the verification of control implementation completed by frontline leaders.<br><br>Typically completed periodically to verify individual critical control(s) for a fatal hazard.<br><br>**Example:** Does each vehicle type have a pre-start that lists what constitutes a safety critical item ('Go/No Go' condition)? Are pre-starts being conducted and vehicles taken out of service where there are defective or missing safety critical items? |
| **Frontline leaders** | Supervisors, team leaders | Check controls are implemented as required.<br><br>Typically as part of task based processes to check critical controls for a fatal hazard at the time of the exposure (e.g. in the field).<br><br>**Example:** Has the team conducted a pre-start on the vehicle? Does the documented pre-start match the vehicle condition? If a safety-critical item was missing or defective was the vehicle removed from service? |
| **Frontline team members** | Operators, maintainers, contractors | Checking of critical controls as part of their implementation.<br><br>Typically conducted task-by-task to check critical controls are in place for fatal hazard before the exposure.<br><br>**Example:** Have I completed a pre-start on the vehicle to confirm no safety critical items are missing or defective (zero 'no go' faults)? |

* Risk owners and control owners would typically be assigned from this organisational level and complete this level of verification.

## What was ECM's verification experience?

The site-specific CCM process had commenced, and the underground business unit site leaders started conducting verification activities and reporting results. The frontline supervisors were pretty comfortable with conducting the field verifications as part of their daily routine. The managers and risk owners started working to a schedule of verifications.

The verification questions started revealing a number of non-conformances or 'reds'. Many of these could be addressed in the field in the moment, such as re-instating a barrier that was meant to be in place to prevent entry into a high-risk area. But others required actions to be raised in the system, such as the case where the site procedure and training did not clarify when barriers are required to be installed.

## How did ECM respond to gaps in critical controls?

There were a mix of views from the working group on how to respond to situations where a verification identified a 'red'. One view was that any failed critical control should trigger the same response as a breach of a safety standard or 'Golden Rule', prompting an investigation and likely result in disciplinary action. Others disagreed, emphasising that a punitive approach would discourage honest and accurate reporting.

It was agreed that they would not implement hard rules and they needed to encourage open and frank reporting. Without this, improvement would be difficult.

## How do you know if CCM is working?

**Welcome 'bad' news!**
ECM experienced a significant increase in the number of critical controls reported as 'amber' (not fully working) or 'red' (ineffective) in the first nine months of their CCM refresh project. Other companies had reported similar findings. This typically reflects an improvement in the quality of critical control verifications and an improved reporting culture. ECM concluded that this increase in information about how well controls are working in practice was very valuable and required careful management.

ECM emphasised the importance of this increase in reporting. They ensured managers responded in a positive manner – knowing that it is easy to reduce reporting by reacting in a negative way. They understood weaknesses in critical controls always needed investigating but in a way which avoided blame and kept the focus on improving the critical controls. The failed controls were almost certainly always there but not previously reported.

ECM also understood that perfection is a very rare commodity and there would always be some controls not working as intended. If all controls were 'green' they understood that this was unlikely and in itself required investigating. Whereas 'red' or 'amber' controls attracted understandable attention.

Follow along with the next learning example

# Step 9: Evaluate and Improve Critical Controls

**Target Outcome:** The critical controls are evaluated for their effectiveness and outcomes are reported to the right people in the organisation so that appropriate actions are taken to continuously improve the critical controls.

**Action 1:** Evaluate critical control effectiveness → **Action 2:** Take action based on results → **Action 3:** Reporting on critical control effectiveness

## Action 1: Evaluate critical control effectiveness

The final process step is for the risk owner, with input from control owners, to step back from the process and periodically and thoroughly evaluate whether the critical controls are adequately designed and effectively implemented to prevent or mitigate the unwanted event. This step may occur for individual critical controls, but will typically be completed at the fatal hazard or unwanted event level. The evaluation compares the actual performance to the expected performance, as defined in the Critical Control Performance Specification (Step 5).

To evaluate the effectiveness of a critical control, it is necessary to assess it from two dimensions:

- **Control adequacy (design)** – the extent to which a fully functioning control is able to meet its objective (purpose). That is, the design of the control is known to be able to perform as expected.
- **Control implementation effectiveness** – the extent to which the control is actually implemented (operating) and performing as expected.

The approach to evaluating effectiveness is summarised in Figure 8.

To do this, the evaluation should draw upon and bring together information from various sources, but particularly findings and insights gathered from the verification activities along with incident data. **It is important to remember the absence of incidents should not be taken as evidence alone that the critical controls are effective.** The verification results provide an essential (proactive) view of the critical controls performance.

It is also important to use the evaluation step as an opportunity to periodically cross check against the current industry practices and learnings in regard to the management of the fatal hazard.

**Note:** It may be necessary to review the organisations incident investigation methods to ensure the investigation process includes an assessment of the status of critical controls and gathers information on causation where the critical control had failed or was absent. Many common incident investigation methods do not adequately explicitly address this point.

Figure 8: Approach to Evaluating the Effectiveness

## Action 2: Take action based on results

If the control is not performing as expected, it is necessary to investigate and understand the reasons for the underperformance to formulate the actions to be taken, which may include:

— review the inherent design of the control.

— strengthen the performance requirements and/or supporting activities, or

— replace the control with a more reliable control, or

evaluate options to reduce the inherent exposure relating to the task, equipment or activity.

## Action 3: Reporting on critical control effectiveness

A key feature and benefit of the CCM process is the ability to make the effectiveness of the critical controls visible throughout the organisation, from the frontline workforce through to the executive and ultimately the board. The former being important, as they are the ones actually exposed to the fatal hazard, and the latter as they need this information to be able to gain assurance on the managerial control of the fatal hazard.

This reporting can take many forms, but organisations have reported benefits in reporting the outcomes in the form of a traffic light report, to indicate whether the controls are fully effective, partially effective or ineffective (or similar rating system) – refer to learning example on the next page.

### How did ECM go about evaluating their critical controls?

The CCM Lead and HSE Manager worked with the site leadership team on how to evaluate the critical controls and how to decide what action was appropriate.

The risk owner for ‘Fall of ground’, was very keen to do so and started gathering relevant verification data, a summary of incidents in the last six months, along with outcomes from a recent geotechnical audit. They also reviewed outcomes and learnings from two recent events that happened in peer companies. They used the information drawn from these sources to conduct a formal evaluation of the critical controls using the ECM criteria for control effectiveness (red/amber/green).

The ‘Ground Support’ control was identified as being currently ‘ineffective’ (red), due to a number of issues around the quality of support installation, particularly in the older areas of the mine.

The outcomes from the evaluation were summarised and reported at the monthly site leadership meeting. The key issues were also escalated to the ECM senior management, who originally instigated the CCM programme. An example of the report is included on the next page.

Follow along with the next learning example

## How did ECM use open reporting to engage the workforce?

ECM used the bowtie format to give feedback to the workforce on the effectiveness of the critical controls. For each unwanted event a simplified poster sized version (A1 size) of the bowtie was prepared. These were available both electronically and posted in prominent locations including meeting and refreshment rooms onsite. Each poster had the following information:

- The name of the risk owner.
- The critical controls, with each having a unique identifier and control owner (where different to the risk owner).
- Critical controls were colour coded to reflect the result of the last verification ie green, amber or red.
- Beneath the colour coded bowtie there was a list of the critical controls.
- Against each critical control a short description (max 180 characters) was provided explaining:
  - why it was green/amber/red (or not evaluated)
  - action taken or underway to rectify the critical control, if it was amber/red or not evaluated
- The results of the two previous verifications were also shown.

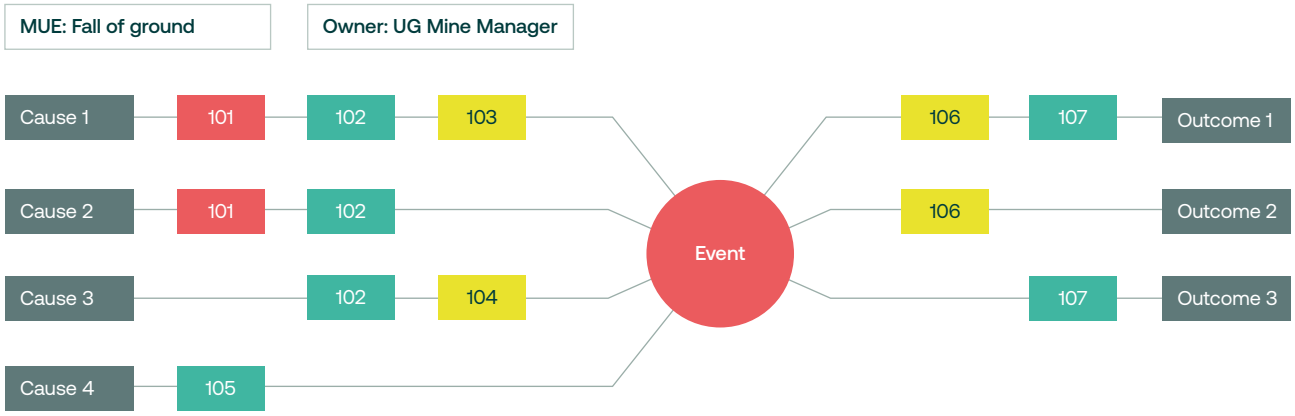
Making the status of each critical control clearly visible (as a result of the colour coding and comments) to all persons from the frontline workforce to senior leaders demonstrably improved the understanding of the importance and status of critical controls.

## What was reported to the ECM executive and board?

There was initial concern about making gaps in critical controls visible to the ECM executive and board. The COO reassured the group that such information is exactly what the board will be looking

for to gain assurance that the process is working. They emphasised that these risks should not receive any less prominence in reporting than other significant risks or other types of health and safety.

### Figure 9: Simplified Bowtie




### Table 10. Status/Verification Table

| ID | Critical Control | Control Owner | June | Sept | Dec | Comments | Actions |
|---|---|---|---|---|---|---|---|
| 101 | Ground support | UG Mine Manager | ● | ● | ● | Repeat issues in the quality of support installation, particularly in older production areas. Commission independent review of ground support integrity. | 1, 2 |
| 102 | Realtime geotechnical monitoring and alerts | Tech Superintendent | ● | ● | ● | No issues since calibration occurred in August. | - |
| 106 | Barriers and exclusion from high-risk areas | Operational Superintendent | ● | ● | ● | Recent non-conformance highlight need to update the UG Safety Standard and training to clarify barricading requirements for preventing access into high-risk areas. | 3, 4 |

# Monitoring and Reporting

06

The CCM process provides an effective means to gather insights into the performance of critical controls. The processes to monitor and report on the performance of the process and the critical controls - across all levels of the organisation - is central and of utmost importance Monitoring how well CCM is working.

No single measure can confirm whether CCM has been successfully implemented; effectiveness must be judged through a combination of verification findings, control performance trends, and organisational learning. Long periods without a fatal incident should not be relied upon as the signal that critical controls are working effectively. Conversely, investigations into severe incidents when they do occur often show that a critical control was either not in place (absent) or failed (ineffective). Furthermore, they demonstrate that such deficiencies were either not identified or known and not reported prior to the incident. CCM provides a means to proactively identify and address such deficiencies before an incident occurs. Within this context, the following are indicators that can be monitored to determine if the CCM process is working effectively:

## Reporting on the CCM process

Clear and effective reporting, both upward and downward through the organisation, is critical to successful CCM implementation and effective risk management. A summary of the typical reporting requirements is included in Table 11. Determining what is to be reported, to whom and at what frequency are key decisions for the organisation and will also be influenced by the site and organisational structures and governance model.

## Indicators of CCM effectiveness

- Frontline team members and leaders are able to explain the purpose of the critical controls and how they work,
- Verifications are being conducted across the site's risk profile and to adequate quality,
- Verifications routinely find some critical controls are not meeting the expected performance,
- The workforce is comfortable in reporting deficiencies in critical controls and leaders respond positively to encourage reporting,
- The results of verifications and the 'health' of critical controls are clearly and routinely reported to all relevant team members and stakeholders, and
- Actions to remedy defects in the design or implementation of critical controls are effective and taken in a timely manner (e.g. action closure status, action quality).
- Frequency and recurrence of potentially fatal incidents linked to absent or failed critical controls.
- Learnings from critical control verifications and investigations are incorporated back into CCM content.

**Table 11. CCM Reporting Responsibilities**

| | Title | Responsibilities |
|---|---|---|
| **Corporate level** | Board | Receive and discuss reports on the organisation-wide implementation of the CCM process and on fatal hazard and critical control 'health' periodically (e.g. on a quarterly/six monthly basis) |
| | Executive and senior leaders | Review and discuss reports on the organisation-wide implementation of the CCM process and on fatal hazard and critical control 'health' periodically (e.g. on a monthly/quarterly basis) |
| | HSE Leader/Business reporting | Receive and collate reports on fatal hazard and critical control 'health' from all sites, and produce corporate reports |
| **Site level** | Site senior leaders (e.g. general managers and senior managers) | Monitor, review and discuss monthly reports on the site implementation of the CCM process and fatal hazard and critical control 'health', and feed up to corporate-level reporting |
| | Operational leaders (e.g. managers and superintendents) | Report and discuss results from verifications and critical control 'health' to risk owner and site senior leaders |
| | Frontline leaders (e.g. supervisors and team leaders) | Report on results from verifications and CCM activities |

# Embedding and Sustaining CCM

07

To fully embed and sustain CCM requires intentional and ongoing action across the many different areas covered in this Guide. The following is a short list of key actions that may help. The CCM Maturity Model (Appendix D) is another tool designed to help an organisation with the journey to fully embed CCM.

### Actions that may help to embed and sustain CCM

- Senior leaders actively and visibly supporting, promoting and giving prominence to CCM, and personally verifying critical controls and reinforcing the importance of reporting gaps ('reds' and 'ambers'),
- Formalising the appointment of risk and control owners to elevate accountability and authority (e.g. appointment letters and inclusion in role objectives),
- Involving the frontline leaders and workforce in key decisions around CCM design and content changes,
- Regular reporting and feedback to the workforce on the status of critical controls, both in terms of the controls that are and are not working well,
- Tracking and reporting on the status of actions to address gaps,
- Using various channels to communicate key messages and share successes in CCM implementation,
  - » Ensuring CCM connects and integrates with other risk-management processes and routines, such as;
  - » Workforce training
  - » Pre-shift/toolbox meetings
  - » Pre-task hazard and risk analysis
  - » Work planning and scheduling
  - » Hazard management plans, safe work instructions and standard operating procedures
  - » Incident investigation and lesson-learnt processes
- Using technology that makes the end users experience of CCM as easy and useful as possible,
- Using data to monitor how well the CCM process is being implemented and whether critical controls are effective in practice, including identifying trends and insights that may indicate 'weak signals' and precursers to critical control failures, and
- Applying strong governance over potential changes to the scope, process or content.

### Ensuring the ongoing management of change

It is inevitable there will be changes that will affect the CCM process. These changes should be reviewed and managed as per any other change that affects health and safety. Typical changes that may affect CCM include:

- Change in the scope or boundary of the approach,
- Adding new or updated fatal hazards, unwanted events or critical controls,
- Updates to content based on findings or learnings,
- Changes to the organisational structure affecting allocation of accountabilities to roles or individuals, and
- Changes in regulations or codes that affect CCM process or content.

# Glossary of Key Terms

08

This is not a definitive list of risk management terminology. The focus is on the key definitions and acronyms associated with critical control management used in this document.

**Bowtie analysis (BTA)**
An analytical method for identifying and reviewing controls intended to prevent or mitigate a specific unwanted event. It visually presents the controls in a form representative of a bowtie.

**Cause**
A brief statement of the reason for an unwanted event (other than the failure of a control).

**Consequence**
A statement describing the final impact that could occur from an unwanted event. It is usual to consider this in terms of the maximum reasonable consequence.

**Control**
A physical object, human action or combination of an object and action that, of itself, directly prevents an unwanted event or mitigates its consequence. Its performance can be specified, measured and verified.

**Control effectiveness**
A measure of the performance of the control(s) in managing the fatal hazard, considering the adequacy of its design and implementation (operating) effectiveness, also often referred to as control health.

**Critical control**
A control for a fatal hazard, which is crucial to directly preventing an unwanted event or mitigating the consequences of the event. The absence or failure of a critical control would significantly increase the likelihood of the unwanted event or the severity of its consequence despite the existence of the other controls.

**Critical control management (CCM)**
A process of managing the risk of fatal hazards that involves a systematic approach to ensure critical controls are in place and effective.

**Critical control performance specification**
A document that summarises the key information for a critical control, including defining its objective, performance requirements, support activities and associated verification activities. Also commonly referred to as a summary sheet or performance standard.

**Control owner**
Nominated person responsible for ensuring an individual critical control for managing a fatal hazard and unwanted event(s) is adequately designed and effectively implemented.

**Erosion factor**
A factor that can lead to the control failing, eroding or being compromised.

**Fatal hazard**
A hazard that can lead to an unwanted event with the potential to result in individual or multiple fatalities or life-altering illnesses. In the context of CCM, the fatal hazards to be included are those that meet the scoping criteria defined by the organisation.

**Hazard**
Something with the potential for harm. In the context of people, assets or the environment, a hazard is typically any energy source that, if released in an unplanned way, can cause damage.

**Mitigating control**
A control that eliminates or reduces the consequences of the unwanted event.

**Monitoring activities**
Continuous or ongoing observing or measuring to detect deviation in critical control performance in real time or over time. Monitoring may occur with respect to an individual critical control or condition (e.g. atmospheric monitoring) or it may look at trends from data (e.g. verification findings over time).

**Preventative control**
A control that reduces the likelihood of an unwanted event occurring.

**Risk**
Risk is the combination of the likelihood that an unwanted event could occur and the severity of its potential consequences. In the CCM process, risk is understood primarily through the potential consequences of fatal hazards, rather than the perceived likelihood of those events.

**Risk owner**
Nominated person with the accountability for ensuring the critical controls for managing a fatal hazard and unwanted event(s) are adequately designed and effectively implemented. Typically appointed from the most senior level of line management applicable to the scope of the fatal hazard.

**Subject-matter expert**
A person who has deep knowledge or expertise in a particular field or topic.

**Supporting activity**
An activity, process or source of information that supports or enables the control to perform as required.

**Unwanted event**
A situation where a hazard is released or occurs in an unplanned way, creating the potential for harm.

**Verification activities**
The process of checking the extent to which the performance requirements set for a critical control, are being met in practice. This will usually involve verifying the implementation of the critical control and on occasions verifying its design.

**A note on terminology:** There is no one term used in the industrial world to describe those rare but disastrous incidents that can occur in aviation, maritime and rail transport, the petroleum industries (upstream and downstream) and the chemical processing industries. Each industry tends to develop its own language and labels. The mining industry adopted the term fatal hazards and unwanted event.

# Appendices

09

# Appendix A

## Roles and Actions in Relation to Critical Control Management

| Who | Role | Knowledge | Example actions (Responsibilities) |
|---|---|---|---|
| **Board and executives** | Strategic oversight and governance over the management of fatal hazards and unwanted events | — Know and understand why a focus on fatal hazards and CCM is needed.<br>— Know how CCM fits with the organisation's broader strategies.<br>— Know the fatal hazards and unwanted events in the organisation.<br>— How to interpret information to gain assurance over the CCM process and effectiveness of critical controls. | — Seek information to gain an understanding of the fatal hazards and unwanted events in the organisation.<br>— Visible endorsement and advocacy of the organisation's CCM strategy and plan to manage fatal hazards and unwanted events.<br>— Review information to obtain assurance that the CCM process and critical controls are adequately designed and effectively implemented. |
| **Senior leadership team (e.g. General managers and senior managers)** | Strategic leadership on the implementation of CCM | — Know and understand why a focus on fatal hazards and how the CCM approach fits with the broader strategy – key messages for why the organisation is doing CCM.<br>— Thorough understanding of the process steps and terminology.<br>— Know the fatal hazards and unwanted events under their control.<br>— Know and understand the critical controls and their purpose.<br>— How to conduct critical control verifications relevant to their role.<br>— How to respond to the outcomes from critical control verifications, in a manner that encourages open reporting.<br>— How to interpret, use and action findings from verifications and reports – including the effectiveness of the critical controls under their control.<br>— Know the responsibilities of being a risk owner – where assigned. | — Define the organisation's purpose, scope, strategy and approach to CCM.<br>— Actively promote and explain the purpose and importance of CCM and support others to understand their roles.<br>— Assign roles, provide resources and allocate time to enable the effective implementation of CCM.<br>— Review and approve the fatal hazards and unwanted events, critical controls, performance requirements and verification activities.<br>— Formally appoint risk owners and control owners (including themselves).<br>— Actively participate in formal and informal critical control verification activities.<br>— Setting the tone to foster a positive CCM culture by role modelling expected behaviours (refer to Appendix B).<br>— Actively monitor and evaluate the critical controls, including fulfilling the role of risk owner as assigned.<br>— Endorse and resource identified actions and opportunities to strengthen critical controls.<br>— Monitor measures and gain feedback on the overall effectiveness of the CCM implementation. |

| Who | Role | Knowledge | Example actions (Responsibilities) |
|---|---|---|---|
| **Operational leaders (Managers and superintendents)** | Make CCM work within their area of responsibility, and personally conduct critical control verifications | — Know why a focus on fatal hazards and the purpose of CCM (key messages).<br>— Working understanding of the process steps and terminology.<br>— Know the fatal hazards and unwanted events under their control.<br>— Know and understand the critical controls and their purpose and requirements.<br>— How to conduct critical control verifications relevant to their role.<br>— How to respond to the outcomes from critical control verifications, in a manner that encourages open reporting.<br>— How to interpret, use and action findings and data from verifications and reports. Including the effectiveness of the critical controls under their control.<br>— Know their responsibilities of being a control owner – where assigned. | — Participate in activities to identify and define fatal hazards and unwanted events, critical controls and associated requirements.<br>— Actively promote the importance of CCM and confirm frontline workforce understand their role in the process.<br>— Personally carry out critical control verifications and where necessary delegate to personnel with appropriate capabilities.<br>— Record and report on results of critical control verifications.<br>— Monitor the quality and completion of critical control verifications and actions to close gaps.<br>— Actively seek out, recognise and respond positively to feedback on critical control performance.<br>— Use data and feedback to gather insights and take action to strengthen critical controls.<br>— Participate in event (incident) analysis to understand critical control performance.<br>— Monitor and evaluate critical controls, including fulfilling the role of control owner as assigned. |
| **Frontline leaders (e.g. Supervisors and team leaders)** | Support and verify the implementation of critical controls | — Understand the fundamentals of the process steps and terminology.<br>— Know the fatal hazards and unwanted events relating to the work/tasks under their control.<br>— Know and understand the critical controls and their purpose and requirements.<br>— How to conduct critical control verifications relevant to their role.<br>— How to respond to the outcomes from a critical control verification, in a manner that supports the frontline.<br>— How to escalate issues and suggest improvements | — Participate in activities to identify and define critical controls.<br>— Check CCM documentation, such as Critical Control Performance Specifications or Standard, accurately reflect actual circumstances (Work as Imagined versus Work as Done).<br>— Actively engage and support teams to ensure critical controls are understood and they have what is required to ensure they are effectively implemented.<br>— Integrate conversations about fatal hazards, unwanted events and critical controls into daily routines, such as pre-shift meetings, debriefs and in-field interactions.<br>— Conduct critical control verifications to check the controls are in place and working.<br>— Record, report and share results of critical control verifications completed.<br>— Openly encourage and respond positively to feedback on challenges and barriers to critical control implementation.<br>— Stop work where a critical control is absent or ineffective, or support and recognise others who do.<br>— Take action to close gaps in critical control implementation and escalate issues as needed.<br>— Report incidents (actual and potential) noting where a critical control was absent or failed. |

| Who | Role | Knowledge | Example actions (Responsibilities) |
|---|---|---|---|
| **Frontline team member (e.g. Employee/ contractors)** | Implement critical controls | — Basic understanding of the process and terminology.<br>— Know the fatal hazards and unwanted events relating to their work/tasks.<br>— Know and understand the purpose of critical controls and their requirements.<br>— Go/No Go criteria for critical controls.<br>— How to escalate issues and suggest improvements. | — Participate in discussions on fatal hazards, unwanted events and critical controls at pre-starts (and debriefs).<br>— Conduct pre-task checks to identify fatal hazards and confirm critical control requirements.<br>— Put critical controls in place as needed, following pre-task analysis, procedures, processes or routines.<br>— Check critical controls are in place and working before commencing tasks.<br>— Apply Go/No Go criteria and stop and seek help from leader if a critical control is absent or ineffective (even if uncertain).<br>— Report incidents (actual and potential) relating to critical control failures.<br>— Feed up any ideas and input into the review of critical controls and event learning (investigations). |

### Supporting Roles (Operate in conjunction with line managers and SMEs as required)

| Who | Role | Example actions (responsibilities) |
|---|---|---|
| **HSE and Risk** | Custodianship of the CCM process | — Advice and support to the organisation on the CCM process as a whole – particularly nominated risk and control owners.<br>— Technical advice on specific fatal hazards, unwanted events and control methodologies.<br>— Provide ongoing implementation support to operations, to integrate and embed CCM processes.<br>— Liaise with other SMEs/functions who support CCM (reporting, training, coaching, etc).<br>— Governance of documentation and management of change in CCM, including changes in fatal hazards, unwanted events and control profile.<br>— Ensure CCM data and reporting is structured to give insights and provide relevant and targeted information to stakeholders.<br>— Custodians of workflows to support the CCM process. e.g. liaising with line leaders and HR when assigned owners move roles, to ensure responsibilities are reassigned. |
| **HR** | Monitoring staffing in safety-critical roles | — Support to line management and other SME groups in recruiting and developing critical roles in implementing CCM.<br>— Custodians of the organisational chart and managing changes to role profiles, as they relate to CCM. |
| **Learning and Development (L&D)** | Develop L&D solutions | — Design and support delivery of L&D solutions to build CCM capability in conjunction with HSE.<br>— Custodians and updating of CCM related training materials in conjunction with HSE. |
| **Business Reporting** | Design-in' integrated reporting on CCs and CCM | — Ensure CCM reporting is designed to work alongside other business critical reporting systems. |
| **Communications** | Support effective CCM communications | — Support development of the CCM key messaging.<br>— Prepare a CCM communication plan to ensure key messages get to the required audience.<br>— Develop supporting CCM communications materials. |
| **Information Technology** | Support technology to enable CCM | — Ensure the technology that supports CCM functions effectively and is administrated efficiently. |

# Appendix B

## A Guide to Foster a Positive Critical Control Management Culture

Leaders can foster an effective CCM culture within an organisation by the intentional actions they take. The following table suggests actions for leaders to ensure CCM is embedded as a sustained imperative.

| Leaders should... | Leaders should not... |
|---|---|
| — visibly promote the purpose and importance of CCM and support others to understand their role in the process.<br>— give CCM prominence and keep it on the agenda at meetings and in one-on-one discussions. | — send mixed messages on the purpose of CCM and the reason for the focus on critical controls.<br>— give prominence to discussions on lagging injury measures (e.g. TRIFR). |
| — actively seek evidence about the effectiveness of critical controls and quality of verification activities.<br>— make informal 'visits' and conduct in-field verifications to find out about critical controls. Be curious and use humble enquiry to understand the realities of work, safety challenges and how critical controls are working in practice. | — wait for something to go wrong before making enquiries about the critical controls.<br>— assume critical controls are working well in practice without evidence. |
| — establish systems to actively monitor and report on the effectiveness of critical controls. Requiring the findings, especially what is not working, to be socialised throughout the organisation<br>— respond strongly to 'weak signals' that indicate a drift in critical control performance. Be clear on expectations around actions that need to be taken. | — blindly trust that monitoring and reporting systems have been established and are active without evidence. |
| — encourage open reporting by responding constructively and welcoming 'bad news' about critical controls. That is, 'embrace the red' – irrespective of where it comes from in the organisation.<br>— seek input from different perspectives, including from those that are actually exposed to the hazards and use the controls. | — react negatively to bad news about critical controls or show displeasure that will reduce the chance that personnel will report control failures. |
| — instil a sense of unease and vulnerability to critical control failures, by querying and seeking evidence where there is repeated good news about critical controls – 'challenge the green'. | — be complacent and accept 'green' as good, particularly where there are unsupported assertions that all is well with critical controls – expect evidence. |
| — adopt a 'learning first' mindset, recognising that information on inadequate critical controls is an opportunity to improve.<br>— be curious and seek to understand the underlying reasons where a verification or incident has revealed a critical control was absent or not working as intended. | — blame individuals for inadequacies in critical control implementation. Blame stifles learning and improvement. |
| — seek out opportunities to challenge whether the critical controls are the most reliable available and any ways they can be further strengthened. | — accept the status quo as the best that is available. |

# Appendix C

## Planning and Readiness Self-Assessment Tool

Before embarking on CCM an organisation should assess if it is ready and has the required understanding to properly scope the approach. It also should know it has, or can access, the skills, knowledge and resources to implement CCM to a high standard. The most important ingredient is to have buy-in from senior leaders.

This checklist provides a tool to help an organisation assess their readiness and identify key aspects to consider in planning for commencing or strengthening CCM.

| Project readiness and planning tasks | |
|---|---|
| **Part 1 – Readiness**<br>The following questions can help to determine if an organisation has the required understanding, commitment and capacity to commence CCM implementation. | **Check when complete** |
| Are there enough senior leaders that 'buy-in' to the need to commence CCM – to form the 'guiding coalition'? That is, enough senior leaders that:<br>— recognise what prevents injuries cannot be relied upon to prevent fatalities,<br>— acknowledge that injury rates have no predictive power for fatalities,<br>— will commit to the hard work and the multi-year effort, and<br>— have a genuine desire to learn from what is discovered. | ☐ |
| Is there adequate capacity (bandwidth) to enable leaders to invest the time and effort to support and sustain the approach? | ☐ |
| Is there a realistic understanding of the current state of the organisations' safety maturity, from which CCM can be built? | ☐ |
| Have any other major projects or changes been assessed in terms of whether they may materially impact (conflict or complement) the success of the approach? e.g. competing transformation agendas that materially distract from the efforts (restructures, industrial actions, closures, etc)? | ☐ |
| Is there adequate frontline support (and trust) to instigate the initiative (to create the 'volunteer army')? | ☐ |
| Have key initiatives from prior safety reviews/diagnostics been substantially completed (or postponed)? | ☐ |
| Is there a person(s) within the organisation who has adequate understanding, knowledge and experience in CCM to help lead the programme (or has access to the programme)? | ☐ |

| **Part 2 – Scoping and strategy (strategic)**<br>The following questions can help to define the scope and strategy for CCM. | **Check when complete** |
|---|---|
| What is the driver(s) for implementing CCM? That is, why has the organisation decided to go down the path? | ☐ |
| What is the goal/objective for what the CCM approach is ultimately aiming to achieve? | ☐ |
| What may successful CCM implementation look like, and how could it be measured? | ☐ |
| What types of events is the CCM process aiming to prevent? That is, the criteria or 'severity threshold' that would trigger an unwanted event to be included. | ☐ |
| What parts of the business are expected to be included or excluded? | ☐ |
| What is the governance structure for the project? Both to initially approve the scope, strategy and plan, and to provide ongoing oversight. | ☐ |
| Who are the key stakeholders and what are their needs? Consider internal and external. | ☐ |
| What is the preferred delivery approach (model)? This could range from deploying across the whole organisation once, or a region at a time, or starting with a pilot site. | ☐ |
| What are the approximate timeframes for the likely major project milestones? | ☐ |
| What are the key decisions that need to be made in terms of alignment and integration with other HSE, risk or assurance systems or enterprise technologies? | ☐ |

| Project readiness and planning tasks | |
|---|---|
| **Part 3 – Planning (tactical)**<br>The following questions can help in preparing a project plan | **Check when complete** |
| What are the specific project objectives? | ☐ |
| What is the project governance structure? | ☐ |
| What is the allocation of key roles and responsibilities (who will do what)? | ☐ |
| What are the key project steps and actions? (See summary list at end of section) | ☐ |
| What is the timeline for the key project steps and actions? | ☐ |
| What finance (budget) is needed for the project? What is the mechanism to track spending? | ☐ |
| What is the communication plan to target messages to the various stakeholder audiences? | ☐ |
| What is the plan to develop and implement an education/training package for the variety of roles involved in CCM implementation? | ☐ |
| What are the specific project objectives? | ☐ |

## Critical Control Management Steps, Target Outcomes and Supporting Actions

| Phase | Step | Name | Target Outcome | Supporting Actions |
|---|---|---|---|---|
| Plan | 1 | Planning the process | A strategy and supporting plan that describes the scope of the project, including what is to be done, by whom and the timeframes. | 1. Assess readiness and prepare for change.<br>2. Project scoping and strategy.<br>3. Develop a plan. |
| Develop | 2 | Identify fatal hazards and unwanted events | Identify and summarise the fatal hazards and unwanted events to be managed. | 4. Identify hazards and unwanted events.<br>5. Select the fatal hazards and unwanted events for the process.<br>6. Assess opportunities to reduce exposure through design.<br>7. Describe the fatal hazards and unwanted events. |
| | 3 | Identify controls | Identify controls for each unwanted event. | 8. Identify controls using definition.<br>9. Sort controls from supporting activities. |
| | 4 | Select critical controls | Identify the critical controls for each unwanted event. | 10. Select critical controls using criteria.<br>11. Summarise the critical controls for each fatal hazard and unwanted event. |
| | 5 | Define critical control performance | Define the critical controls' objective, performance requirements, and how they are to be supported and verified in practice. | 12. Define the critical control's objective.<br>13. Define the critical control's performance requirements.<br>14. Identify the support activities for the critical controls.<br>15. Define verification or 'checking' activities. |
| | 6 | Assign accountability | Assign owners for the fatal hazards, critical controls and verification activities. | 16. Assign ownership and accountabilities. |
| Implementation | 7 | Critical control implementation | Develop a plan to tailor the CCM content to meet local context and implement the critical controls. | 17. Tailor the CCM content to the site level.<br>18. Endorse site-level CCM materials.<br>19. Engage operational personnel in CCM implementation.<br>20. Implement critical controls. |
| | 8 | Critical control verification | Conduct verification activities and take corrective action as required. | 21. Conduct verification activities.<br>22. Act on verification outcomes. |
| | 9 | Evaluate and improve critical controls | Evaluate the critical controls for their effectiveness and report outcomes to the right people in the organisation so that appropriate actions are taken. | 23. Evaluate critical controls effectiveness.<br>24. Take action based on results.<br>25. Report on critical controls effectiveness. |

# Appendix D

## CCM Maturity Model

**What is the CCM maturity model?**
The model is designed to support organisations to critically assess the maturity of their existing approach to critical control management (CCM) for managing fatal hazards and unwanted events. It is structured as a journey chart with each step describing an increased level of CCM maturity. The output from the model can then be used by an organisation to develop actions to improve their maturity level in a progressive manner. The model can be applied at any level of the organisation but is most applicable at a site level, to assess how it is being applied operationally in practice.

Maturity models have been used in other parts of the mining and metals industry, including for psychosocial risk management, diversity and inclusion, closure, security management, social performance, and human rights. They are intended to drive performance and transformation across the mining and metals industry.

**How was the maturity model developed?**
The model was developed by building upon the original model contained in the 2015 Guide and incorporating learnings from CCM implementation. The revised model is aligned to the updated Critical Control Management Good Practice Guide (2026). The model was also reviewed by the ICMM Health and Safety Working Group along with an objective external expert review.

**How is the maturity model designed?**
The CCM maturity model is a matrix that contains 13 elements that are grouped into five categories, and four maturity levels. These are described in Tables 1 and 2 below.

**Table 1. Categories and Elements of CCM**

| Category | Elements |
|---|---|
| **Planning (Process Step 1)** | — Planning the process |
| **Design and development (Process Steps 2–6)** | — Identify fatal hazards and unwanted events<br>— Identify controls and select the critical ones<br>— Define critical control performance and assign accountabilities |
| **Implementation (Process Steps 7–9)** | — Implement critical controls<br>— Verify critical controls<br>— Evaluate and improve critical controls |
| **Leadership and engagement** | — Leadership mindsets<br>— Individual (workforce) mindsets and engagement |
| **Program management** | — Governance and change management<br>— Competence and capability<br>— Monitoring and reporting<br>— Assurance |

**Table 2. Definition of Maturity Levels**

| Level | Descriptor | Description |
|---|---|---|
| 1 | Limited | — CCM is at its infancy<br>— Not commenced or only just starting<br>— Limited understanding and application<br>— Primarily compliance driven |
| 2 | Emerging | — CCM is at basic level<br>— Processes are evolving<br>— Notable gaps in process and implementation<br>— Some appreciation for critical control focus |
| 3* | Established | — CCM is in place<br>— Consistent approach<br>— Some gaps in process or implementation<br>— Evidence of proactive implementation and operational learning |
| 4 | Leading | — CCM is fully embedded<br>— Processes are integrated and sustained<br>— Continual improvement and learning focus<br>— Operationally owned and driven |

* Level 3 within the model broadly represents meeting the intended or target outcome.

**How to conduct an assessment?**

Users should review the descriptions for each level within the maturity model and, using the focus question as a prompt, objectively determine which level best reflects the current situation within their organisation, site or team. Note that the descriptions are not prescriptive, and the entire description does not need to be present for an organisation to consider itself at that maturity level. A user should refer to the CCM Guide, specifically the target outcomes and actions for each step, to assist with the assessment.

The assessment should be undertaken with involvement or engagement with a cross section of stakeholders, to understand not just whether the process is in place but to gauge how it is applied and received in practice operationally.

The maturity model is not intended to be 'verified' in any way, nor is evidence required to support a organisation's own assessment of its maturity. However, companies may seek an independent maturity assessment undertaken by a third-party, at their discretion.

Table 3. Critical Control Management Maturity Matrix

| Characteristics | Focus question | 1 – Limited: In its infancy | 2 – Emerging: Basic application | 3 – Established: In place | 4 – Leading: Fully embedded |
|---|---|---|---|---|---|
| **Planning the process (Step 1 and Appendix A)** | How considered are the organisation's strategy and plan to establish and improve CCM? | — No formalised plan for implementing or improving CCM. | — Basic plan for implementing or improving CCM. | — Strategy and plan in place.<br>— Signed off by senior leaders.<br>— Supported by adequate implementation resources.<br>— Process design decisions documented. | — Strategy and plan are core to operating model and integrated into business planning.<br>— Endorsed by executive and board. |
| **Identify fatal hazards and unwanted events (Step 2)** | How systematic and structured is the approach to identifying and defining the fatal hazards and unwanted events? | — Informal or unstructured approach.<br>— Inherited or adopted and not tailored to local context. | — Identified using basic methods and/or as required by regulations.<br>— Some tailoring to local context. | — A systematic and structured approach, using a range of inputs.<br>— Clearly described.<br>— Aligned to agreed scope.<br>— Signed off by senior leaders. | — Proactive approach with periodic reviews incorporating internal and external lessons learnt (wider industry and peer companies).<br>— Assessment of opportunities to remove hazards through design. |
| **Identify controls and select the critical controls (Steps 3 and 4)** | How systematic and structured is the approach to identifying controls and selecting critical controls? | — Informal or unstructured approach.<br>— Inherited or adopted and not tailored to local context. | — Selected using basic methods.<br>— Meets the definition.<br>— Some tailoring to local context. | — Selected using a systematic and structured approach.<br>— Assessed using criteria.<br>— Tailored to context.<br>— Signed off by senior leaders. | — Challenged against reliability criteria to confirm they are the best available.<br>— Incorporates internal and external lessons learnt (wider industry and peer companies). |
| **Define critical control performance and assign accountabilities (Steps 5 and 6)** | How well defined and tailored are the critical control performance requirements and accountabilities? | — Not documented or an unstructured approach.<br>— Materials are inherited or adopted and not tailored to local context. | — Defined at a basic level.<br>— Some tailoring to local context. | — Defined in a structured way, including accountabilities.<br>— Tailored to local context.<br>— Reviewed with workforce.<br>— Signed off by senior leaders. | — Represent 'work as done' and incorporate operational learnings.<br>— Risk/control owner assigned and exposed to industry good practices and learning opportunities. |
| **Implement critical controls (Step 7)** | How consistent is the implementation of critical controls? | — Informal or ad hoc implementation. | — Varied levels of implementation.<br>— Driven more by compliance. | — Consistent implementation, as per expectations.<br>— Commencing integration with internal documents, work planning and management processes and daily routines. | — Embedded and integrated into designs, internal documents, work planning and management processes. |
| **Verify critical controls (Step 8)** | How established and consistent is the verification of critical controls? | — Informal or ad hoc verification. | — Varied levels of verification.<br>— Driven more by targets.<br>— Moderate quality. | — Consistent verification, as per expectations and to adequate quality. | — Embedded as part of operating routines.<br>— High quality. |
| **Evaluate and improve critical controls (Step 9)** | How established and consistent is the evaluation and improvement of critical controls? | — Informal approach.<br>— Sporadic actions, typically reactive from investigations or audits. | — Basic approach.<br>— Some improvement actions proactively identified. | — Established and consistent approach in place.<br>— Use of lead and lag data.<br>— Deviations from expected performance investigated and actioned within define timeframes. | — Embedded approach.<br>— Integrating operational learnings including from 'work as done', involving frontline teams.<br>— Targeted actions to strengthen or replace control to increase reliability.<br>— Includes sharing with others. |
| **Governance and change management** | How formalised and established is the governance over CCM? | — Informal or unstructured approach. | — Basic structure and approach.<br>— Largely at site level. | — Formalised structure and approach in place at both operational and corporate levels. | — Structures and processes are embedded.<br>— Integrated within the operating model.<br>— Oversight of CCM is up to the executive and board level. |
| **Competence and capability** | Do personnel have the required capability and competence to fulfil their nominated roles? | — No formalised approach to assigning roles and confirming capabilities.<br>— Limited onboarding (training) into CCM process. | — Personnel in nominated roles have basic capabilities and competence due to onboarding (training) processes. | — Personnel have required capability and competence to fulfil their nominated roles (e.g. Risk and control owners, and verifiers). | — Ongoing coaching and development activities to strengthen capabilities and competence. |

| Characteristics | Focus question | 1 – Limited: In its infancy | 2 – Emerging: Basic application | 3 – Established: In place | 4 – Leading: Fully embedded |
|---|---|---|---|---|---|
| **Monitoring and reporting** | How established are the processes to monitor and report on CCM and the status of critical controls? | — Ad hoc and informal approach to monitoring and reporting CCM and critical control status. | — Basic approach to monitoring and reporting, such as reporting on the quantity and breakdown of activities (e.g. verifications and actions). | — Established at operational and corporate levels – frontline to exec/board.<br>— Use of dashboard and reports (traffic light reports) to monitor and report how well CCM is working and give insights into the status of critical control.<br>— Regular feedback to workforce. | — CCM status and critical control effectiveness has prominence and is core to operational and corporate reporting – visibility from frontline to board.<br>— 'Bad news' is welcomed.<br>— Advanced analytics and narrative-based reporting. |
| **Assurance** | How formalised and established is the approach at site/corporate to gain assurance on the implementation of CCM? | — Informal or unstructured approach. | — Basic approach with a compliance focus.<br>— Limited to no independent assurance. | — Formalised approach in place at site and corporate levels.<br>— Some degree of independent assurance. | — Embedded approach.<br>— Integrated as a core part of the organisation's assurance model.<br>— Assurance reports are presented at the executive and board level. |
| **Leadership mindsets (see Appendix B)** | What is the mindset and practices of leaders in terms of applying the process and fostering a CCM culture? | — Leaders are driven primarily by compliance and lagging metrics.<br>— Only limited understanding and appreciation for a critical control focus.<br>— Leaders see feedback as criticism and can be defensive. | — Some appreciation for a critical control focus.<br>— Some evidence of proactive implementation.<br>— Leaders are beginning to adopt an open mindset to feedback. | — Leaders onboarded on the fundamentals.<br>— See value and accept the focus.<br>— Evidence of proactive implementation and a learning mindset in the way they conduct verifications, receive feedback, respond to gaps and support actions. | — Operationally owned and driven by line leaders.<br>— Actions from leaders visibly promote and foster a positive CCM culture.<br>— Leaders encourage and embrace feedback as an opportunity to learn. |
| **Individual (workforce) mindsets and engagement** | What is the understanding and mindset of individuals in terms of applying a critical control-focused approach? | — Compliance driven.<br>— Only limited understanding and appreciation for a critical control focus. | — Basic understanding and some appreciation for a critical control focus.<br>— Workforce discuss critical controls as part of work planning and management, but general reluctance to raise issues relating to critical controls. | — Workforce onboarded and understand the fundamentals and accept the focus.<br>— Evidence of proactive implementation.<br>— Workforce are generally comfortable to raise issues relating to critical controls. | — Critical control focus is valued and recognised as being core to how work is planned and executed.<br>— Workforce feel psychologically safe to raise issues and question the capacity of critical controls to respond in specific circumstances. |

# Appendix E

## Reference Examples of Fatal Hazards and Unwanted Events

The following table is a list of typical mining and metals related fatal hazards and associated unwanted events based on historical analysis. The wording has been simplified for communication purposes. An organisation should define the unwanted event related to their internal company definitions and specific context.

| Fatal Hazards | | Unwanted Events |
|---|---|---|
| Gravity | **Elevated objects** | — Dropped/falling object. |
| | **Ground/geotechnical** | — Fall of ground underground.<br>— Subsidence event.<br>— Slope failure/fall of ground surface. |
| | **Hoists and winders** | — Shaft/hoist failure |
| | **Lifted or suspended loads** | — Falling or swinging load.<br>— Uncontrolled movement or toppling of lifting equipment. |
| | **Person at heights** | — Fall from height. |
| Thermal | **Explosives** | — Unplanned detonation of explosives.<br>— Flyrock from blast. |
| | **Flammable/ combustible/ explosive materials** | — Underground fire/explosion.<br>— Surface fire/explosion. |
| | **Molten material** | — Molten material contact/ fire/explosion. |
| | **Temperature extremes** | — Exposure to thermal extremes (heat/cold stress). |
| Vehicular/Transport | **Aviation** | — Unplanned movement of aircraft (fixed, rotatory, and remotely piloted aircraft). |
| | **Marine** | — Unplanned movement of vessel (collision).<br>— Uncontrolled release of mooring line. |
| | **Rail** | — Unplanned movement of rail traffic (collision/derailment). |
| | **Vehicles / Mobile Equipment** | — Uncontrolled movement of vehicle (collision or rollover).<br>— Uncontrolled movement of heavy mobile equipment (collision or rollover). |

| Fatal Hazards | | Unwanted Events |
|---|---|---|
| Other Energies | **Chemical** | — Loss of containment of hazardous materials/ substances (acute).<br>— Exposure to hazardous materials/substances (chronic). |
| | **Electrical** | — Exposure to energized electrical conductors (electric shock or arc flash). |
| | **Mechanical** | — Uncontrolled exposure to rotating and moving parts (entanglement and crushing). |
| | **Pressure** | — Uncontrolled release of pressurised energy.<br>— Overpressure event.<br>— Tyre bursts/projectile. |
| | **Radiation (ionizing)** | — Exposure to ionizing radiation. |
| | **Stored energy** | — Uncontrolled release of stored energy. |
| Environmental/Conditional | **Airborne particulates** | — Exposure to respirable particulates above OEL (dust, fumes, mists, and diesel particulate). |
| | **Confined spaces** | — Uncontrolled exposure in confined space (hazardous atmosphere, engulfment, entrapment). |
| | **Hazardous atmospheres** | — Irrespirable (unbreathable) atmospheres. |
| | **Infectious/vector zborne diseases** | — Uncontrolled exposure to Infectious/vector borne diseases. |
| | **Water/slurry/tailings** | — Underground inrush/ inundation.<br>— Surface pit flooding or inrush.<br>— Fall or submersion into water (drowning).<br>— Tailings/impoundment failure. |

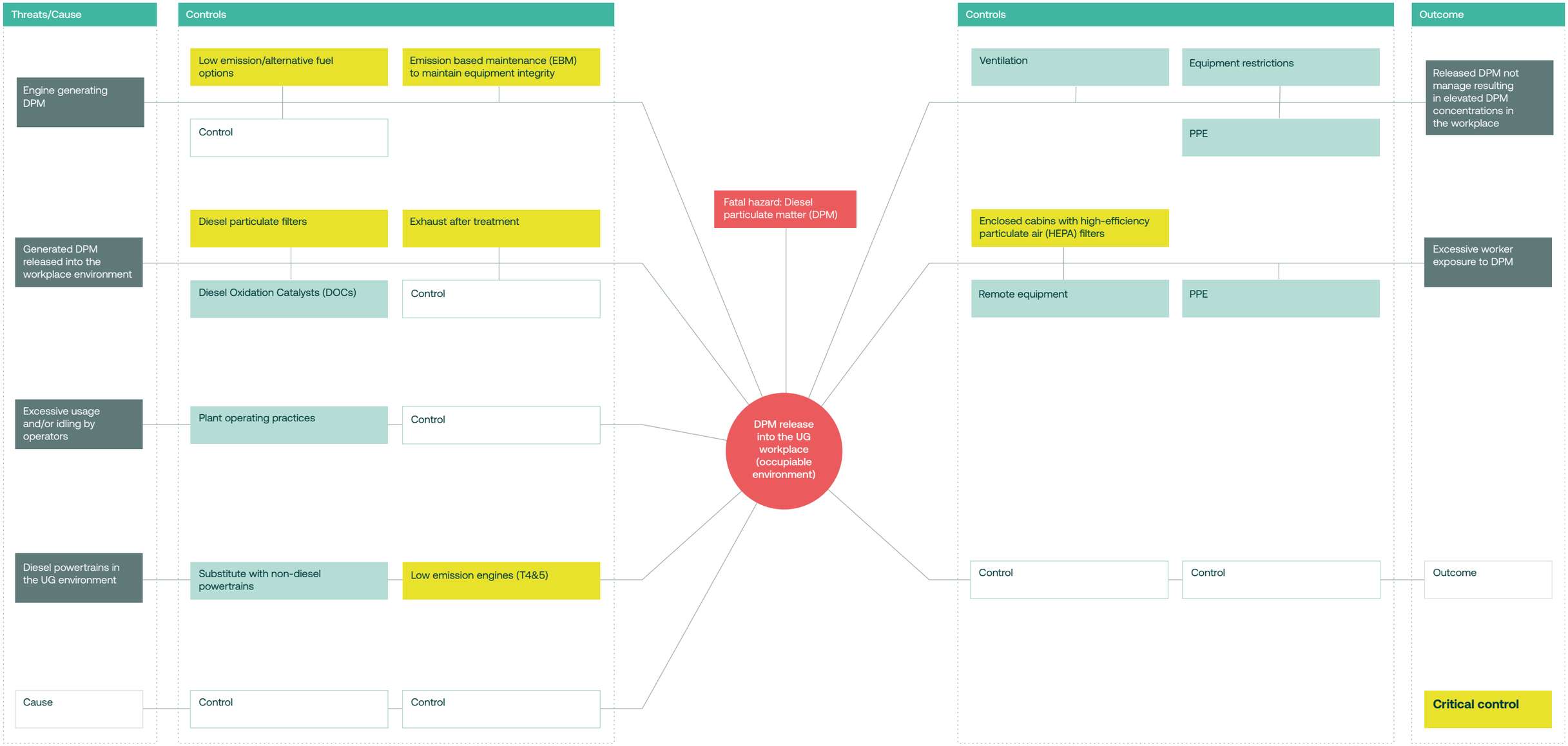
# Appendix F

## Reference Health Example – Diesel Particulate Matter Exposure

### Example Critical Controls for Diesel Particulate Matter (DPM) exposure

| Hazard/unwanted event | Example critical controls | Example support activities |
|---|---|---|
| **DPM release into the underground workplace environment (occupiable environment) exceeding OEL**<br><br>Unplanned and/or uncontrolled release of DPM from diesel engines into the workplace environment<br><br>**Example scenarios:**<br>— Elevated DPM concentrations in the workplace atmosphere<br>— Excessive worker exposure to DPM<br>— Cumulative DPM exposure resulting from multiple diesel machines operating in a panel or level | Low emission engines (T4&5) | — Procurement and engine specification<br>— Engine installation and commissioning<br>— Regular maintenance and servicing<br>— Operator training and awareness<br>— Data management and record keeping |
| | Low emission/alternative fuel options | — Technology assessment and selection<br>— Procurement and supplier engagement<br>— Integration and infrastructure<br>— Maintenance and lifecycle management |
| | Emission based maintenance (EBM) to maintain equipment integrity | — Emissions monitoring protocols<br>— Developing maintenance scheduling based on emission data<br>— Training maintenance and operations staff<br>— Data management systems<br>— Maintenance based on emission thresholds |
| | Diesel particulate filters/exhaust after treatment | — Assessment and specification development<br>— Procurement and supplier engagement<br>— Installation and commissioning<br>— Maintenance and regeneration procedures<br>— Data management and record keeping |
| | Enclosed cabins with high-efficiency particulate air (HEPA) filters | — Design and specification development<br>— Supplier selection and procurement<br>— Installation and commissioning<br>— Operator training and awareness<br>— Maintenance and filter replacement<br>— Cabin airflow and particulate levels testing inside the cabin |

Figure 10: Example Bowtie – Diesel Particulate Matter Exposure



## Critical Control Performance Specification or Standard

<table>
<tr><td>1. Related fatal hazard and unwanted event(s)</td><td colspan="2">DPM release into the UG workplace (occupiable environment exceeding OEL)</td><td>Risk owner</td><td>Underground mine manager</td></tr>
<tr><td>2. What is the name of the critical control?</td><td colspan="2">Emission based maintenance (EBM) to maintain equipment integrity</td><td>Control owner</td><td>Maintenance superintendent</td></tr>
<tr><td>3. What is its specific objective related to the unwanted event?</td><td colspan="2">To ensure that diesel engines operate within specified emission limits by conducting targeted maintenance when emissions exceed set thresholds and verifying effectiveness of exhaust aftertreatment, thereby reducing the release of harmful particulates into the workplace air and minimising workers' health risks.</td><td colspan="2">7. What are the activities to confirm the control is performing as required (verification activities)?</td></tr>
<tr><td>4. What are the control's performance requirements to meet the objective (Performance requirements)?</td><td>5. How could the control be eroded or compromised (Erosion factors)?</td><td>6. What are the activities, processes or sources of information that support or enable the control (Support activities)?</td><td>— Verification of design/support activities</td><td>— Verify implementation (typically in-field)</td></tr>
<tr><td>Targeted maintenance when emissions exceed predefined thresholds (e.g. engine type-based target values for DPM, CO, NO2, and Nox)</td><td>— Equipment failure</td><td>— Raw diesel emissions monitoring</td><td>— Quarterly data analysis</td><td>— Periodic data collection</td></tr>
<tr><td>Realtime emission monitoring systems</td><td>— Insufficient or irregular maintenance can result in controls not functioning as intended</td><td>— Treated diesel emissions monitoring</td><td>— Fleet-based emissions target limits</td><td>— Conduct targeted maintenance based on emissions</td></tr>
<tr><td>Emission thresholds and alerts</td><td>— Mistakes made by personnel, such as improper use of equipment or failure to follow safety protocols, can compromise the effectiveness of EBM</td><td>— Engine backpressure monitoring</td><td>— DPM emission register with data visualisation tools</td><td>— Regular emission testing</td></tr>
<tr><td>Scheduled and triggered maintenance intervals</td><td>— Changes in operation<br>— Training deficiencies<br>— Insufficient resources, whether financial, human, or technological, can hinder the implementation and maintenance of effective controls</td><td>— Exhaust aftertreatment reduction efficiency<br>— Emissions monitoring and engine data<br>— Maintenance scheduling<br>— Condition-based triggers to perform maintenance<br>— Equipment emission profiles<br>— Training and planned tasked observation</td><td>— Equipment utilisation information<br>— Scheduled maintenance and trigger criteria</td><td>— Real-time monitoring of emission levels in designated work areas or ventilation districts</td></tr>
<tr><td colspan="3">8. What is the target performance for the critical control?</td><td colspan="2">9. What is the performance trigger for shutdown, critical control review or investigation?</td></tr>
<tr><td colspan="3">Diesel engine emissions, particularly particulate matter (PM), are maintained within applicable regulatory limits and industry standards), typically aiming for a reduction of at least 85–95% referring to DPFs in emissions compared to baseline levels<br>— 100% of diesel fleet part of period emissions testing<br>— 95% of tested engines below specific emission target<br>— 100% of engines above target value scheduled for maintenance<br>— DPM efficiency is greater than 85%</td><td colspan="2">When emission levels exceed predefined, regulatory, or manufacturer-specified thresholds – for example, when particulate matter (PM) levels surpass the maximum allowable limits or when real-time monitoring systems trigger alarms indicating control failure</td></tr>
</table>

# Appendix G

## Connecting Critical Controls to Work Management

A significant point for exposure to fatal hazards, particularly single or double fatalities, within the mining and metals industry is at the task execution level. This includes both routine and non-routine, scheduled and unscheduled (breakdown) work. The identification and control of fatal hazards associated with these tasks relies heavily on the organisation's work management processes. The following table aims to represent how critical control management connects into the work management process.

| Planning | | Set up | Start | Post |
|---|---|---|---|---|
| **Prior to day of task** | **Day of task (Start of shift)** | **Immediately prior to task** | **Immediately prior to task** | **At start of task** | **Post task (End of shift)** |
| **Work design and scheduling to reduce hazard exposure and support critical control implementation** | **Identify and discuss the hazards and critical controls for the tasks at start of shift** | **Assess the hazards and define the critical controls for the task, immediately prior to the task** | **Confirmation of relevant critical control requirements** | **Confirm critical controls are in place before exposure occurs** | **Identify and share improvements and learnings from tasks** |
| **Work planning** | **Pre-start processes** | **Pre-task hazard assessment** | **Permits/ procedures/work instructions** | **Critical control checks/ verifications** | **Task debrief** |
| — What are the hazards and exposures that can be removed or reduced?<br>— What are the specific requirements for critical control implementation?<br>— What capabilities and resources are required for critical control implementation? | — What are the hazards and critical controls for the task?<br>— Are workers equipped with the skills, knowledge, qualifications and resources to implement critical controls?<br>— Do the workers have adequate time to complete the task?<br>— Is the right level of supervision available including to verify critical controls? | — Do workers know the hazards and critical controls for task steps?<br>— What are the hold points for leadership oversight and endorsement to proceed?<br>— Do workers know the 'Go/ No Go' criteria for critical controls?<br>— Do workers know who to contact if required? | — Have workers gained required approvals, such as permits?<br>— Do workers have access to the right information for the task?<br>— Are the hazards adequately managed by these critical controls? | — Are the critical controls in place before the exposure occurs?<br>— Has anything changed? | — Did the work management documentation adequately identify the hazards and critical controls?<br>— Were there any capability or resourcing gaps?<br>— Are there other improvements or learnings to be shared? |

Manage change and adapt to variation in task

# Acknowledgements 09

The development of this document would not have been possible without the input, expertise and support of the individuals and organisations acknowledged below. ICMM greatly appreciates their contributions and their commitment to strengthening critical control management across the industry.

**ICMM Members**
Special thanks are extended to the representatives from ICMM member companies and specifically the members of the Safety Working Group who led the development of the document. Their insights, practical experience and feedback significantly shaped and enhanced this guidance. Their contributions were essential in ensuring the updated CCM approach is grounded in operational reality and applicable across diverse contexts. Contributors included:

— Chair: Diego Barahona, Deputy Chair: James Russ.

— Specific member mentions to: Richie Subramanian, Herman Heukelman, Jorge Franco, Juan Antonio Trujillo, Cas Badenhorst, Andrew Golembka, Brad Neilson, Chris Rose.

**Other Member Contributors:**
Adam Dargusch, Andrew Dullaghan, Jim Ishman, Carolina Pobletereyes, Andrea Fernandez, Daniele Paulino, Kate Bannister, Jamie Young, Joshua Tepper, Ben Maxson, Katherine Hookham, Angela Kent, Quentin Toose, Nathan Cahill, and Rhett de Vries.

**ICMM Team**
This guidance was led by Michael Duvenhage from ICMM, with support from Owen Newton, Nic Benton, Dana Cartwright, Bryony Clear Hill, Danielle Martin, Marine Godard, and Kira Scharwey.

**Consulting Team**
ICMM would also like to express its gratitude to Anthony Deakin and Peter Wilkinson of Glasshouse Consulting for their expert advice, analytical input and support throughout the development process.

ICMM stands for mining with principles.

We bring together a third of the global metals and mining industry, along with key partners to drive leadership, action and innovation for sustainable development, ultimately delivering a positive contribution to society.

Through collaboration, ICMM member companies set the standard for responsibly produced minerals and metals in a safe, just and sustainable world.



**ICMM**
53-64 Chancery Lane
London, WC2A 1QS
United Kingdom

+44 [0] 20 7467 5070
info@icmm.com

icmm.com

January 2026