Enabling breakthrough safety, productivity, and engagement in mining

August 2021

1. Mine fatalities are becoming ever more challenging to reduce

Miners in Australia have reduced fatalities by an order of magnitude over the last two decades. According to Worksafe Australia, the five-year average fatality rate in 2019 was 2.9, while the actual numbers for 2018 and 2019 were 3.7 and 2.9, respectively.

Figure 1: Mine fatality rate/100 000 constructed from Worksafe Australia data

Societal norms are continuing to evolve, and the desire to reduce work-related deaths to zero, find expression in ever more stringent legislation. The problem we see is that the safety principles (Safety-I) that have brought us this far have probably delivered what they can. Part of the reduction achieved is due to Mining executives expressing the belief that safety trumps productivity and following through. A mine that is not operating is obviously much safer than one running at breakneck speed trying to break even or prevent closure. Employees and management are continuously making trade-offs to keep safety and profit within acceptable limits. This trade-off is especially acute for contractors, who are becoming ever more important to the success of miners.

The largest miners are starting to explore engineering-based interventions to try and remove people from dangerous solutions. This is expensive, and complications arise from socio-technical interactions, which introduces other risks. This approach is also not available to smaller miners with limited financial resources.

To enable the organisation's transition to managing safety in the ecological age, we need to understand and break the dynamic that sets up the productivity/safety conflict and prevents progress. This requires a new way of thinking and doing. Safety-II is part of such an approach; it focuses more on changing the conditions of work than trying to prevent individual employees from making errors through implementing more rules and procedures. It also helps to unshackle employees from excessive bureaucracy that limits improvement.

We will show how a systems-based approach, the Productivity Platform, makes the flow of work easier and more productive and frees up managerial time and attention. We will explain how this changes the mining environment focus from reacting to rapidly changing circumstances to one where work requirements are predictable and stable. By getting the work to flow faster, with less effort and more stability, we create the environment that organisations and employees need to adjust safely and productively to the increased complexity in socio-technical systems used in running mines.

2. Miners are stuck in an operational paradigm that works against breaking the productivity/safety trade-off

2.1. The Industrial and Information Ages

The Industrial Age growth mindset in the early 20th century was fuelled by Scientific Management principles of productivity. The work environment was stable, certain, and predictable.

Systems thinking and Human Factors boosted by computer technology offered new and improved alternatives. Industry rally behind "Faster, better, cheaper" in the pursuit of optimised efficiency. However, all is not well. We observe promising Information Age digital tools yielding negative impacts and making operations extremely complicated. As consultants, we have seen many attempts to optimise across the entire system to achieve efficiency. Some software packages are coded on this premise. However, systems thinkers like Russell Ackoff argue that system capability decreases. Eli Goldratt, in his Theory of Constraints (TOC), supports Ackoff's claim. According to McKinsey, productivity in mining, adjusted for declining grade and deeper mines, has dropped 29% in the decade to 2015 [1)]. This is illustrated by figure 2 below.

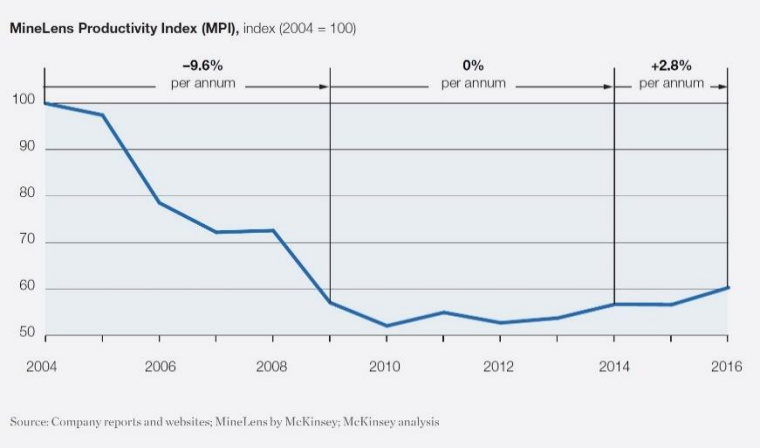

Figure 2: Declining mining productivity

In Figure 3, we show thinking evolving along a series of S curves. In each age, the methods used to carry along the best from previous ages. These methods deliver more and more value until society, technology and the environment start to change. Best practice now starts to struggle to solve prevailing problems. This crises period is shown in the yellow bubbles. New methods emerge, but the dominant methods are strong enough to prevent them from taking off. It is our view that we are currently in the Information age yellow bubble.

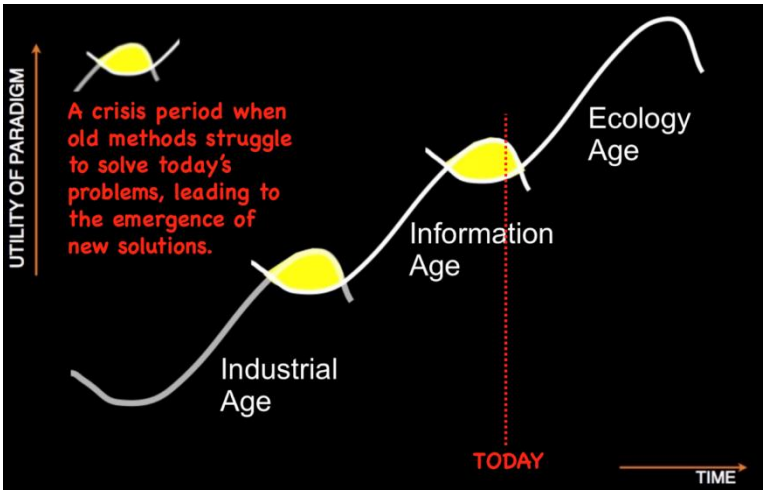

Figure 3: The development of the Industrial, Information and Ecological Ages.[2)]

2.2. Information and Industrial age thinking cannot cope with the Ecological Age

Handling Ecological issues such as Social Licence, engagement and safety solely with the Industrial and Information Age methods will not work.

Mining has become a complex adaptive system. The unexpected emergence of new things means "the whole is greater than the sum of its parts". In the Ecology Age, confusing dilemmas, ambiguous paradoxes, diverse conflicts are natural occurrences.

Management is forced to react to unexpected events on short timescales; this requires Agility from the organisation. But Agility requires a stable base from where the organisation can adapt quickly. The best practice methods employed today contain contradictions that make it difficult to create a stable platform from where Ecology Age problems can be solved.

Two ideas from the Industrial and Information ages are instrumental in destabilising the production system. The first is the idea that all parts of the process should be run at maximum efficiency. [2)] The second idea is that we should optimise the parts of the entire production chain from end to end. This idea could be implemented for the first time during the Information age, as computing power increased and cost reduced. [3)] The combination of these ideas results in a tendency to create balanced capacity production chains, as illustrated in Figure 3. The outcome of this is starvation and blockages, and unstable production flow at output well below design. Cost per unit is significantly higher, and there is an exponential increase in issues that consume managerial span of attention - this is the world of firefighting.

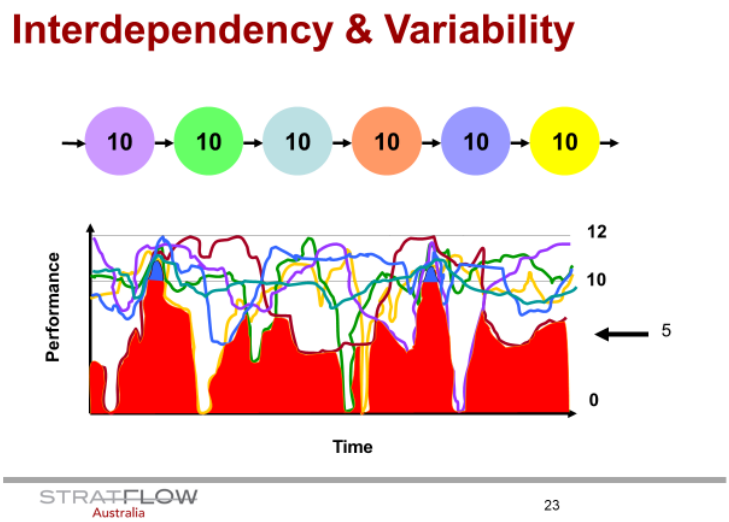

Figure 4: The effect of interdependency and variability on mine output[4)]

In this example, each department in the production chain is able to perform at an average "10" level. However, the actual output is much lower at "5".

This is bad enough, but there is an outcome that is even more problematic relating to trust and cooperation.

As data increased, it seems possible to enforce individual accountability by measuring employees on more detailed KPI's. This injects disharmony into the organisation and reaps diminishing returns. The continuing decline in employee engagement around the world seems to support this contention. (In Australia, from 2013 to 2017, the proportion of employees that are rated as "highly engaged" dropped from 24 to 14%.[5)])

How does this happen? Boston Consulting Group partner Yves Morieux explains:

"…this drive for clarity and accountability triggers a counterproductive multiplication of interfaces, middle offices, coordinators that do not only mobilise people and resources, but that also add obstacles. And the more complicated the organisation, the more difficult it is to understand what is really happening. So we need summaries, proxies, reports, key performance indicators, metrics. So people put their energy into what can get measured, at the expense of cooperation.

And as performance deteriorates, we add even more structure, process, systems. People spend their time in meetings, writing reports they have to do, undo and redo. Based on our analysis, teams in these organisations waste between 40 and 80 per cent of their time, but working harder and harder, longer and longer, on less and less value-adding activities. This is what is killing productivity, what makes people suffer at work.

We need them to cooperate, to trust their co-workers and managers. It is to take a risk, because you sacrifice the ultimate protection granted by objectively measurable individual performance. It is to make a super difference in the performance of others, with whom we are compared. It takes being stupid to cooperate, then. And people are not stupid; they don't cooperate." [6)]

In summary: Without any slack/spare capacity in the system, we are unable to create the stability to meet our mandated goals reliably, month after month. Without stability, trust and cooperation, managers and employees have neither the time nor the ability to deal effectively and quickly with changing priorities.

2.3. Safety-I for the industrial and information age

According to Safety-I [7)], "*things go wrong due to technical, human and organisational causes – failures*
and malfunctions. Humans are therefore viewed predominantly as a liability or hazard. The safety management principle is to respond when something happens or is categorised as an unacceptable risk.
Accordingly, the purpose of accident investigation is to identify the causes and contributory factors of adverse outcomes, while risk assessment aims to determine their likelihood. Both approaches then try to eliminate causes or improve barriers, or both.
This view of safety was developed between the 1960s and 1980s, when performance demands were significantly lower, and systems were simpler and more independent. It was assumed that systems could be decomposed and that the components of the system functioned in a bimodal manner – either working correctly or working incorrectly. These assumptions permitted detailed and stable system descriptions and enabled a search for causes and fixes for malfunctions."
These assumptions do not fit today's world, where systems such as Air Traffic Management (ATM) cannot be decomposed in a meaningful way, where system functions are not bimodal, but rather where everyday performance is (and must be) variable and flexible.

Today most organisations have implemented safety systems chalked full of rules, regulations, policies, and procedures. Congrats! Looks great on paper! But ask yourself: Is it sufficient?

You know it's not enough when you hear employees share their stories about safety:

- "When the last batch of new safety rules was announced, once again, we pushed back hard, but nobody cared to listen. No problem. We know how to ignore them."
- "I've seen reckless unsafe behaviour even though the safety rules are well known and understood. Speak up and stop production? Yah, right."
- "New situations continually arise that were not considered when a safety process was initially designed. So we either stop work and wait for help or create workarounds to get things done our way."
- "In the last compliance training course, I didn't learn anything I didn't know already. But I was in attendance, so I got my name ticked on the checklist. I guess everyone's happy now."
- The latest cost-cutting directive conflicts with our "safety first" initiative. I voiced the dilemma, but it fell on deaf ears."

2.4. Safety-II as an addition to coping with the Ecological age

The dominating safety paradigm has been to focus on what goes wrong, look for failures, improve barriers, and reduce the number of adverse events. Complexity necessitates a change in thinking: Safety isn't created but emerges from workplace conditions. If too many rules and constraints are imposed, Danger can just as easily emerge. When a tipping point is reached, failure ranging from a near-miss incident to a fatality can occur. Workers need to know how to adjust performance to succeed under varying conditions, not under their control.

"By taking complexity theory ideas like the butterfly effect, unruly technology, tipping points, diversity, we can understand that failure emerges opportunistically, non-randomly, from the very webs of relationships that breed success and that are supposed to protect organisations from disaster. Safety is an emergent property, and its erosion is not about the breakage or lack of quality of single components."[8)]

In light of increasing demands and system complexity, we must adapt our approach to safety. While many adverse events may still be treated by a Safety-I based approach without serious consequences, there is a growing number of cases where this approach will not work and will leave us unaware of how everyday actions achieve safety. The way forward, therefore, lies in moving toward Safety-II while combining the two ways of thinking. Most of the existing methods and techniques can continue to be used, although possibly with a different emphasis. But the transition toward a Safety-II view will also include some new practices to look for what goes right, focus on frequent events, remain sensitive to the possibility of failure, to be thorough as well as efficient, and to view an investment in safety as an investment in productivity.

Safety management should therefore move from ensuring that 'as few things as possible go wrong' to ensuring that 'as many things as possible go right'. This perspective is termed Safety-II and relates to the system's ability to succeed under varying conditions. According to Safety-II, the everyday performance variability needed to respond to varying conditions is the reason why things go right. Humans are consequently seen as a resource necessary for system flexibility and resilience. The safety management principle is continuously to anticipate developments and events. The purpose of an investigation changes to understanding how things usually go right as a basis for explaining how things occasionally go wrong.
Risk assessment tries to understand the conditions where performance variability can become difficult or impossible to monitor and control.

Safety-II holds that people should not intervene in other people's behaviour – **we need to intervene in the conditions of their work**. Rather than telling them what they need to do, we need to ask them what they need to do something well, and we need to maximise the number of things that go right. Safety-II says people are the solution, people know very well what to do and how to create safety. Rather than trying to foresee and predict and control their every move, use them as sources of resilience.

3. Enabling the organisation to move from Safety-I to Safety-I &-II

3.1. Why do miners find it difficult to implement Safety-II principles?

Safety-II is about getting as many things as possible to go right and to do it by intervening in the conditions of work (system) and not the behaviours of employees. We saw in the previous section how the balanced capacity system with its emphasis on trying to optimise all parts in isolation leads to moving bottlenecks, production well below what the system is capable of and extreme workflow **instability**. This puts pressure on the frontline to make trade-offs in favour of meeting production targets.

There are other difficulties in creating the agile employee-led momentum required to implement Safety-II.

No two companies (or even business units) are alike. They are complex adaptive systems that perform in unique ways due to their particular organisational history and experience. This is why a formula or intervention that works for one organisation will often not work for another. Change programs that need to inculcate fundamental cultural adjustment are thus difficult to do.

The following obstacles impede progress from Safety-I to Safety-II:

Alignment

- At the executive level, the understanding of work as done is not adequate. It is therefore not clear which actions and strategies will deliver the transition and how different departments need to align to support this.
- Large scale change management projects are difficult to implement and often run aground on cultural issues.
- Many organisations have experienced many amalgamations, streamlining and reorganisations. These are often not fully digested (ending up in a situation where it is unclear who has authority on signing off decisions).

Trust

- Coming from a culture where the assignment of blame after an incident is common, generating the trust required to progress will be difficult. Without trust, frontline and management will not volunteer their energy, ideas or take calculated risks.

Focus/resources

We observe executives responsible for up to 15 projects, with their subordinates having a similar number to handle. This indicates a managerial span of attention overload. Even if the identified obstacles could be removed as part of a brilliantly designed master plan, the resources to manage this will not be available.

3.2. The productivity platform as the starting point for stability

We have demonstrated in more than 90 mining interventions over two decades that applying the Theory of Constraints in mining can increase production flow by between 10% and 40%, and the resultant unit cost reductions were between 10 and 30%. During the years of introducing and applying TOC, amongst other interventions, the mines' output increased and kept on increasing for many years[9)]. The Productivity Platform has the potential, stabilise the flow, increase the output, reduce unit costs and improve safety.

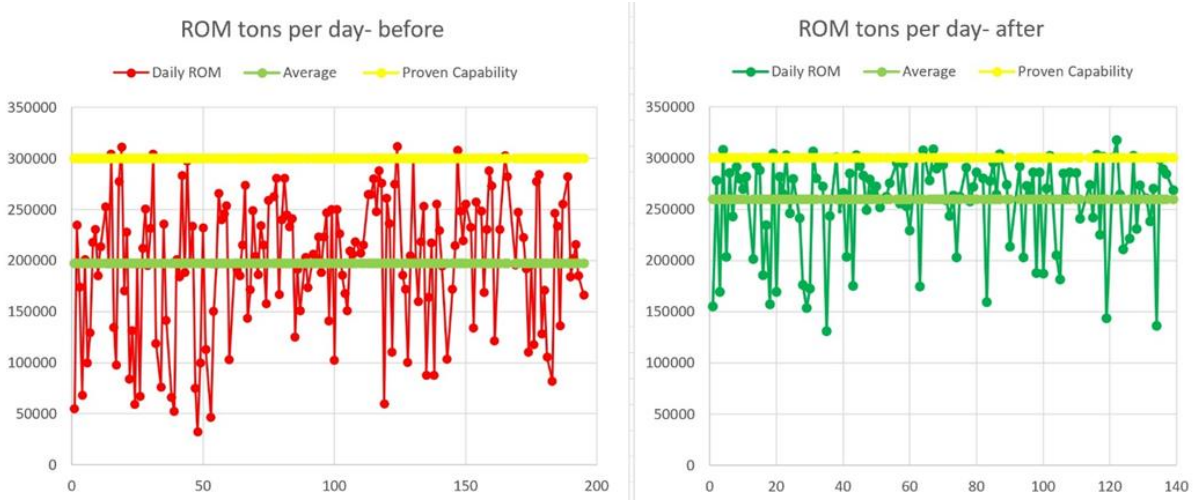

Figure 5: Run of mine performance before and after

The Productivity Platform makes the overall goal of the system clear. It identifies and communicates the role of each person and department in achieving that (by getting work to flow faster through bottleneck areas) and changes the management paradigm to one where we manage the overall system for greatest effectiveness and efficiency. The increased clarity of purpose, advance warning of problems, alignment and trust, enables production flow to increase, using the same resources. We call this state “Superflow in a spirit of calmness” (work becomes easy) makes more time available and takes away the need to force work through the system faster than it can safely handle it.

Figure 6: Dialogue in the flow room

- After a few months of running the daily Productivity Platform Meeting, the bottlenecks have been identified (problems making work difficult),

- The departments/managers/workers are aligned to get increased, stable flow through the bottlenecks.
- Through daily dialogue, all involved understand the work as done characteristics in all areas. Every part of the mining production chain has an effect (with a time delay) on every other part since we continuously cycle from blasting to load and haul, to staking and block preparation, drilling and charging, and back to blasting. This makes the dialogue about issues experienced relating to flow crucial for managing the overall system.
- The visual picture of production flow is accessible to all and enables a shared vision of what needs to be done, especially in short to medium term. Managers are thus able to delegate to subordinates without losing touch with what is happening. Employees now see the purpose of their work and can improve their mastery every day. This environment is also excellent for leadership development and safe to try experiments.

3.2.1. The productivity platform is also a dual management operating system

In pursuit of stability, the productivity platform also creates opportunities for bottom-up, agile teams to address changing priorities and improve the overall flow and maintain the stability of the system. From the pattern of flow observed in the flow room, it becomes possible to identify and communicate obstacles to flow to the entire mine and put together teams to solve these quickly and giving them a forum where progress can be reported on and support provided from other departments. Therefore we also refer to the Productivity Platform as a Dual operating system, allowing both stability and Agility, without interfering in the standard mining operations. [10)]

Figure 7: Kotter's dual management operating system, Accelerate 2012

3.3. How does the stability created by the Productivity Platform enable us up to make the transition in thinking and working that makes implementing Safety-II possible?

The Productivity Platform creates an environment where employees obtain an understanding of work as done vs work as imagined and the areas where employee-led initiatives can make a difference. (In the present environment, management has good reason to believe that workers will not take the initiative to do what is required or that it is too risky to delegate responsibility.) In seeing departments

and personnel transform into star performers, management realises the importance of the system on individual performance and results. This makes it much easier to accept that the focus on error (person) should shift to intervention into the system. It also creates a buffered work environment where the inevitable failure involved with delegation and innovation around addressing obstacles does not affect mandated outcomes.

The Productivity Platform identifies and communicates the few critical areas that require focus (bottlenecks give leveraged returns) and thus generates unity of purpose. By focussing on dialogue around these global objectives and making the contribution of all parties to this visible, community of trust is developed. This is crucial for creating a just culture and for the increased collaboration required with Safety-II.

It creates a work environment that is stable and where work is predictable. It is now possible to shift to proactive management and continually scan for issues and weak signals. Safety-II requires this proactive outlook in order to deliver.

And finally, the productivity platform provides early warning for when demand will exceed capacity and thus leave management sufficient time to implement contingency plans. It also unlocks unused capacity, which reduces the frequency of events where demand exceeds capacity.

Safety-II requires that managers see and act in the world from a systemic point of view (not just individual error). The productivity platform helps them to understand the systemic nature of work and the environment in which we operate. The shift from the world of local optima to global optimisation (flow focussed) requires new global measurements to replace some of the old departmental measurements. This is how the Productivity Platform helps the safety transition along.

But the transition toward a Safety-II view will also include new practices and activities; to look for what goes right, focus on frequent events, remain sensitive to the possibility of failure, be thorough as well as efficient, and view an investment in safety as an investment in productivity.
According to Safety-II, the everyday performance variability needed to respond to varying conditions is the reason why things go right. Humans are consequently seen as a resource necessary for system flexibility and resilience.

Now that we have the productivity platform in place, have gained stability and productivity, and have demand peaks under control, we can start the process of launching Safety-II frontline driven initiatives such as learning teams and collective improvements.

Given their exposure to the overall flow of work and bottlenecks, they now have a much better idea of where work demand exceeds capacity and where workflow needs to be improved. This allows learning teams to focus on areas of leverage and show significant results in a very short period.

3.4. Harnessing the frontline in implementing Safety-II and removing obstacles to work

The following image demonstrates a very important aspect regarding the difference between Safety-I and Safety-II from the point of view of improving safety and productivity. In the Information and Industrial Ages work as imagined could be taken as approximately the same as work as done.

Experts could thus put together policies, procedures based on an ordered world where cause and effect could be specified in advance or identified after an incident through an investigation. This is not longer true, as the following section will show.

Figure 8: Work as imagined vs work as done, Eric Hollnagel 2012

In the world of Safety-I work as done is the same as work as imagined. In Safety-II, we know that this is often not true.

Fundamental to Safety-II is the belief that the system becomes less safe when work is difficult. Our focus should thus be on identifying, strengthening and removing obstacles to the easy flow of work. And we should do this in a way that both management and frontline have a common understanding of the crucial issues that need to be addressed. These obstacles are created by the asymmetry in information flow through organisations. Information on strategy and the translation of that into operational detail works reasonably well (downward communication). However, when work as imagined reaches the frontline, it quickly becomes clear that there is a disconnect with the way work needs to be done. Information about this disconnect does not flow upwards. This means that those with the power and authority to fix this do not get the opportunity.

Why does bad news not flow upwards? Firstly middle-level managers (and executives) believe that it is their job to execute with the resources they have been allocated and that it is doable. In modern organisations, the reality is that no manager controls all the resources required to do an excellent job. Without good horizontal coordination across functional groups, it is not possible to perform

according to expectation. Problems that need systemic solutions thus build up in the organisation and cause work to become more and more difficult to do. Given that managers are promoted based on their ability to execute with what they have got, the ambitious manager will keep quiet about the problems in the system.

Since management often has a poor line of sight towards the work as done vs work as imagined gap, it becomes very difficult to improve the conditions so that employees can become successful. **And if managers are unable to solve this fundamental obstacle, they will not be able to implement and sustain the addition of Safety-II.**

3.4.1. The benefit of Learning teams, Collective Improvements etc

In the flow room, we have created an environment where a selected group of managers and senior employees get an overview of what is happening and where to focus. But this leaves us with the majority of employees having to rely on information fed back from these meetings by their managers. The increased stability and reduced risk allow managers to delegate more opportunities for improvement enabling workers to achieve purpose mastery and autonomy.

Collective Improvements and learning teams allow management and frontline to develop a joint understanding of the interrelated challenges that combine to make work difficult. Work as done becomes visible, and management can design work as imagined to match. It identifies the crucial leverage points (seldom more than two) that need to be addressed to improve the flow of work. By allowing resources to focus on only a few leverage points, the resource constraint is alleviated, and the alignment between work as done and work as imagined multiplies the impact. By providing a common vision of what needs to be done to management and workers can align what they do and support one another. Momentum is built and maintained by achieving success early in the project, and a positive feedback loop ensues.

A crucial outcome of this is that trust develops. Trust can only develop between a group of people as they work together and achieve success in a work environment. Collective Improvements create an environment where we can bypass most of the obstacles identified earlier.

4. Conclusion

Mining organisations generally plan and organise work according to Command and Control principles. There is great value in this way of structuring operations, but when it goes too far, it leads to a focus on the activities and performance of individual departments and employees at the expense of overall system performance. “A mechanical perspective encourages internal competition, gaming, and blaming. Purposeful components (e.g. departments) compete against other components, ‘game the system’ and compete against the common purpose. When things go wrong, people retreat into their roles, and components (usually individuals) are blamed.”[11)] Under these circumstances, unity of purpose and trust disappears.

In this manner, managers destabilise the flow of work and overload their cognitive abilities since everything becomes important and in need of constant attention and adjustment**. Work becomes difficult** for them and their subordinates.

The information factory (information on work is sent away to be processed by people not involved in the daily work and returned in the form of control measures), which is a consequence of Command and Control management, follows from "work as imagined" at the senior level being considered the same as "work as done" at the coalface. Given that the work environment in mining is dynamic and shows a high degree of variability and interdependency, efforts to control work remotely shackles the ability of subordinates to compensate and adjust properly to the situation as it unfolds.

The most powerful management efforts focus on changing the accepted best practice management paradigms. John Seddon says, “Forget your people. Real leaders act on the system. Real leaders redesign the system to meet demand. When leaders act on the system, customers cheer, costs fall, and the culture change comes free.” [12)]

The Productivity Platform enables mine management to work according to systems principles. It creates a platform where managers and employees can safely practice the new way of managing without getting rid of the beneficial characteristics of Command and Control and Hierarchy.

It reduces the levers to control to the absolute minimum and unshackles employees to do what needs to be done for the good of the whole. It creates an environment where employees have a purpose, can achieve mastery and have more autonomy.

It exposes the difference between work as imagined and work as done. This is a crucial step towards improving the overall system.

Stability:

Managing according to the new paradigm creates superflow in a spirit of calmness and expands the capabilities and outcomes of the system under management control. In other words, **work becomes easy.** Managers and employees can coordinate across functional departments and deliver exceptional results with current resources. The critical boundary where safety issues start to appear shifts outwards, allowing much higher productivity while improving safety. More time is available to discuss the effect of operations on safety and to find innovative ways of mitigating these issues.

We have now created a platform from where we can handle emerging threats in an Agile fashion using the dual operating system aspects.

Agility:

The tools of Safety-II, learning teams, collective improvements and learning teams can now be implemented as part of a virtuous feedback loop. (by focusing on what makes work difficult, safe to try and safe to fail experiments can be run, without risk of jeopardising the productivity or safety of the organisation.) Complexity science tells us that simple interactions between workers, customers, suppliers, citizens, etc., can lead to uncertainty, confusion, and unexpected outcomes. Instead of fighting it, you can take advantage of complexity itself by using sense-making techniques and group wisdom to resolve systemic problems. You can also apply simple heuristics, safe-to-fail

experimentation, networking, pattern recognition tools to guide change. Techniques such as Learning teams, Collective Improvements, Improvements teams and other bottom-up interventions can now be launched without management having to worry about the impact of experiment failure on the bottom line. Should an experiment fail, as many do, the system has spare capacity to recover. The improved visibility and forward-looking nature thereof makes delegation even easier. By allowing our employees initiative and the ability to make a difference, we create purpose mastery and autonomy and dramatically improved level of engagement.

This article dealt primarily with mining, but by identifying the leverage points in project, service, manufacturing and supply chain environments, we can adapt the productivity platform to deliver radically improved productivity and safety to these areas also.

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