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BARRIERS AND INCENTIVES: THE APPLICATION OF COMPREHENSIVE RISK MANAGEMENT IN THE US UNDERGROUND COAL MINING INDUSTRY

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INTRODUCTION

The International Organization of Standards defines risk as "*the effect of uncertainties on achieving objectives* (15)." In mining, many uncertainties can influence the outcome of personal or professional objectives and are often difficult to predict. Risk management, the minimization and control of adverse effects from exposure to identified risks, is a well-established concept that can summarized as "being smart about taking chances" (12). Risk management now consists of management processes unique to numerous organizations across many industries, as varying sectors encounter a variety of needs, including the analysis and mitigation of risks related to physical security, product liability, information security, various forms of insurance, regulatory compliance, and workplace safety (12).

The reoccurrence of multiple fatality events in the US mining industry, especially the underground coal sector, suggests an opportunity for improved methods of major safety hazard identification, assessment, and mitigation. A risk management approach would include ready identification and mitigation of these risks, inclusive stakeholder engagement, and rapid integration. While many solutions to reducing the risk of mine disasters have been proposed including stricter regulation and improved technology, a comprehensive risk management approach has yet to be fully integrated in the US mining industry.

In December of 2006, R. Larry Grayson of the National Mining Association's Mine Safety Technology and Training Commission called for "*a new paradigm for ensuring safety in underground coal mines, one that focuses on systematic and comprehensive risk management as the foundation from which all life-safety efforts emanate* (7)."

A risk management approach has already been implemented with success in Australia's minerals industry as part of a transition during the mid-1990s from a prescriptive based health and safety attitude to a more proactive, duty-of care [risk-based] philosophy (13, 16, 17).

FUNDAMENTAL ELEMENTS OF RISK MANAGEMENT TECHNIQUES

The fundamental components of a comprehensive risk assessment/management program are well-established within the realm of mining health and safety. *Figure 1* depicts the elements of a typical mining hazard management framework. The first step in any safety-based risk management system is to identify and assess hazards by their location, nature, and magnitude within a mine. Next, a decision is made about choosing to eliminate, mitigate, or tolerate each hazard. Ideally, a hazard will be eliminated during the design stages of mining, though dynamic mining conditions often require continuous improvement and reevaluation of existing hazard controls. If elimination is not possible, hazard mitigation actions can consist of methods, rules, equipment, competencies, or other mechanisms. If a hazard is simply tolerated, as many inherent mining hazards must be, then specialized administrative controls must be utilized to minimize losses. During this process, the performance of each action is monitored and modified as needed (13).

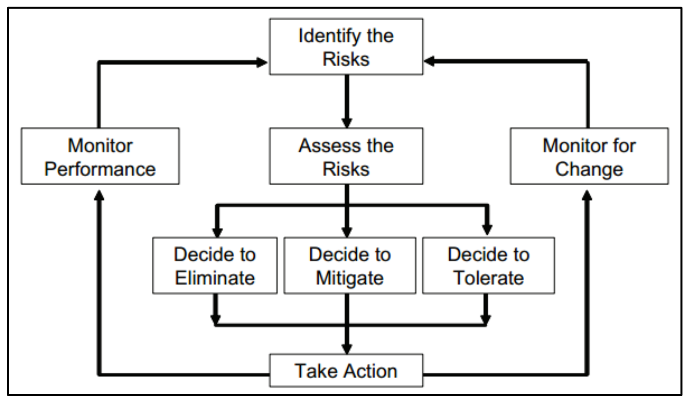

Figure 1. Principal Elements of a Risk Management Framework (13).

In 2008, the National Institute for Occupational Safety and Health (NIOSH) conducted a study in which Major Hazard Risk Assessment (MHRA), a risk management process developed by the Australian mining industry, was implemented as a pilot project at ten mines across the United States to lower the risk arising from exposure to site-specific major hazards. These mines ranged in size and commodity type from small-scale aggregate quarrying operations to larger underground longwall coal mining operations. The ten case studies demonstrated that most US mines have the capability to successfully implement a major hazard risk management process, and that the Australian MHRA methodology produced additional preventive controls and recovery measures which complemented those currently in place (13).

The prescriptive safety standards of the US mining industry rely heavily on the preexistence of standardized rules. This foundation is based on past experiences and current industry Best Practices, producing technically detailed regulations requiring constant review and occasional modification. However, these universal standards sometimes fail to identify and manage unique hazards associated with unconventional and dynamic mining conditions (13). In the United States, this methodology has led to a reactive approach towards hazards in which new regulation is often only imposed following major disasters. Such a standardized approach towards health and safety can de-incentivize the use of leading practices and create an industrywide culture of compliance. This is very consistent with the observations of an Australian mine manager made in 1998 prior to the introduction of risk-based regulation in Australia: "*An emphasis on* *prescriptive regulation leads to mediocrity when a dose of realism is needed in this industry. Prescriptive operation and safety regulations lead to under-performance with everyone from the chief executive officer down abdicating their performance responsibilities and routinely filling in the required forms without addressing the real problem. Culture and attitude to safety must be widespread, with responsibility spread to everyone under a duty of care regime. A duty of care regime can reflect individual mine circumstances and places the onus on both mine management and employees to assess and manage safety risks within their sphere of control* (6)."

HISTORICAL BACKGROUND: REGULATION OF THE US MINING INDUSTRY

The Federal Mine Safety and Health Act of 1977, generally referred to as the Mine Act, is the legislation which currently governs all coal, metal, and non-metal mines in the United States, including surface and underground operations and mills. The Mine Act was preceded by both the Metal and Non-Metallic Safety Act of 1966 and the Federal Coal Mine Safety and Health Act of 1969, commonly recognized as the Coal Act. The Metal and Non-Metallic Safety Act was the first federal statute to directly regulate non-coal mines (30). However, enforcement of the advisory standards created by Metal/Non-Metal Act was minimal due to vague and undefined language in the legislation (32). The passage of the Coal Act was largely due to public uproar in response to a coal mine disaster in Farmington, West Virginia. The explosion and ensuing fire occurred on November 20, 1968, at the Consol No. 9 Mine killing 78 miners (9). This tragedy initiated a movement to standardize health and safety practices for US coal mines and increase enforcement of these standards to prevent the occurrence of similar disasters in the future. As with previous legislation, widespread public criticism of the federal regulation of the coal industry pressured Congress to impose harsher penalties on mines and mine operators who failed to properly mitigate unsafe mining practices and hazards. The Coal Act pioneered many regulatory standards for the coal mining industry and was more stringent than any previous legislation governing the industry. Provisions of the Coal Act included increased federal enforcement authority, establishment of criminal penalties for violations, and the adoption of specific procedures for the development of mandatory health and safety standards (31).

While the Coal Act was seen as a major step forward for health and safety standards in the coal mining industry, the non-coal mining sector still suffered from insufficient enforcement of health and safety standards. After the Sunshine Mine disaster of 1972 killed 91 miners, the Secretary of the Interior created the Mining Enforcement and Safety Administration (MESA), a new departmental agency – separate from the US Bureau of Mines – responsible for enforcing the safety and health standards promulgated by prior federal statutes (26). Although no major non-coal disasters occurred in the five years following the establishment of MESA, the average fatality rate for metal and non-metal miners (including underground mines, surface mines, and mills) increased to more than 75 percent of that for coal miners during this time period, up 25 percent from the previous five years (32) suggesting that enforcement of statutory regulations was not achieving desired workforce safety outcomes.

The major thrust of the Mine Act was the consolidation of US coal and metal/nonmetal mines through a single piece of legislation. The Mine Act replaced the Coal Act and repealed the Metal and Non-Metallic Mine Safety Act of 1966, discontinuing advisory standards and state enforcement plans in the metal and non-metal sector (5). The Mine Act effectively expanded the jurisdiction of the Coal Act to include metal and non-metal mines, improving legal provisions for non-coal miners, and increasing Federal enforcement power of safety standards for metal and non-metal mines. The Mine Act also transferred responsibility for the health and safety of miners from the Department of the Interior to the Department of Labor, establishing both the Mine Safety and Health Administration (MSHA) and the Federal Mine Safety Health and Review Commission to provide for the independent review of MSHA enforcement actions (23). MESA was placed under the newly created MSHA in an effort to unify major federal safety and health programs in the Department of Labor. The passage of the Mine Act affected virtually every aspect of mine health and safety in the US.

Since its creation in 1978, MSHA has administered the provisions of the Mine Act, enforcing and facilitating compliance with the mandatory safety and health standards set forth by the act. The MSHA enforcement structure contains several divisions, including the Coal Mine Safety and Health (CMS&H) division, which is further divided into 11 district offices overseeing the separate coal mining regions across the nation (25). Under the Mine Act, each underground coal mine in the United States must undergo at least four annual inspections by MSHA, during which mine compliance with Title 30, Part 75 of the Code of Federal Regulations (Mandatory Safety Standards Underground Coal Mines) is examined. Additionally, “gassy” mines and mines deemed particularly dangerous may receive supplementary inspections (5). MSHA is specifically prohibited from giving any advance notice to the mine regarding a routine inspection, and MSHA inspectors may enter the mine property without a warrant. All violations found during inspections must be cited, are subject to civil penalties, and must be corrected within an established timeframe. The MSHA penalizing inspection scheme was created to encourage compliance with the provisions and safety standards of the Mine Act.

Through years of modification, mine safety regulation in the US has developed into a highly prescriptive system emphasizing tough enforcement and harsh penalties for violations. Despite this approach, several catastrophic accidents resulting in multiple fatalities – most recently the Upper Big Branch coal mine explosion of 2010 – have occurred since the passage of the Mine Act. In 2006, following the Sago Mine explosion in West Virginia which killed 12 miners, Congress enacted the Mine Improvement and New Emergency Response Act (MINER Act). The MINER Act established mine-specific emergency response plans in underground coal mines, created new regulations for the sealing of abandoned areas, and dramatically raised civil penalties for violating the law (23). However, harsher penalties and increasingly prescriptive regulation did not prevent the Upper Big Branch disaster from occurring. The mine had been issued 76 orders concerning failures to comply with the approved ventilation plan in the four months prior to the explosion (34). This citation record indicates not only the failure of the mine to maintain its ventilation system, but the failure of any intervention by the US enforcement system to effectively prevent unsafe conditions from recurring within the mine (22).

In addition to propagation of the mandatory health and safety standards contained within 30 CFR 75 through the Coal Act and the Mine Act, further requirements and revisions have been proposed and implemented over the years. Additional safety requirements can be expected with emergent technologies and increasing sophistication in mining methods. For example, in 1996, MSHA issued final rules establishing new safety standards for the use of diesel-powered equipment in underground coal mines regarding allowable surface temperatures, and newly required methods for conducting methane tests in deep cuts due to improved testing methods (14). A major issue with this rulemaking procedure is that once a new rule or requirement is issued as part of the CFR, it becomes difficult to modify even when new knowledge or technology makes the final ruling moot or incorrect.

The issue of modification becomes especially prevalent when the rulemaking process is abbreviated due to pressure on MSHA to impose new health and safety standards following a major disaster (8). For instance, following the Sago Mine explosion, passage of the MINER Act required underground mines to implement wireless two-way communications and an electronic tracking system within three years. Unfortunately, ambiguous language in the regulation – particularly concerning the term “wireless” – caused confusion among both mine operators and product manufacturers regarding the necessary performance requirements of such systems. Also, prescriptive regulation has led to reluctance by US Mine Operators to implement best safety practice if variable mining conditions exist at their operation or if the practice may potentially affect future mine developments. Alteration of an MSHA approved mine plan (ventilation, roof control, etc.) is nearly impossible after submitted if any part of the resubmitted plan offers modification that might be perceived as providing less protection to miners than the previous version.

THE SUCCESSFUL APPLICATION OF RISK MANAGEMENT IN RELEVANT INDUSTRIES

Prescriptive regulations have long dominated governance of the hazardous working environment of underground coal mining in the US, due largely to two features of such an approach – explicitly stated requirements and easily enforced legislation. However, there is an inherent weakness due to a disincentive for organizations to be innovative, as the compliance approach focuses on minimum standards rather than industry best practice. These systems also may not consider that institutional management of work may introduce unforeseen hazards if inadequately organized (4). A regulatory approach called risk-based governance has more recently emerged in the safety regulation of the coal mining and other heavy industries around the world where various stakeholders (government, employers, workers, etc.) have become more comfortable eliminating compliance requirements. Risk-based governance, which emphasizes placing responsibility for controlling workplace hazards on those who create the hazards, coincides with the implementation of comprehensive risk management systems by employers to fulfill their operations' unique safety requirements (34). A milestone in global occupational health and safety legislation and practice occurred in 1972, when the Chair of the National Coal Board (NCB) in the UK, Lord Robens, delivered the Robens report. This report was in part a response to the Aberfan disaster of 1966 which resulted in the deaths of 116 children (109 of which were aged 7 to 10), after an impoundment failure. The findings of this report stated that there was too much law in occupational health and safety, and the area needed to be simplified, and should encourage self-regulation. Lord Robens found that a shift needed to occur in the balance between "prescriptive" and "goal-setting" legislation towards the latter, in order to encourage self-regulation (29).

Despite broad adoption in coal mining in other countries, and other high hazard industries in the US, the diffusion of risk-based management techniques in the US coal industry has been slow. In contrast, commercial aviation and defense have strong safety records with low accident rates. The US Federal Aviation Administration (FAA) developed the Aviation Safety Reporting System (ASRS), a voluntary system which allows pilots and other airplane crew members to confidentially report near misses and accidental rule violations for the purpose of improving safety. This system provides incentives which waive operator liability for self-reporting of incidents, and has contributed to the identification and management of many safety hazards present in commercial aviation (3). Today, the accident rate for the commercial aviation industry is relatively low considering that there are over 10 million commercial airplane flights domestically per year. In 2010, for example, U.S. Air Carriers flew 17.5 million miles with only one major accident (24). In 1963, the United States Nuclear Navy instituted a "wildly successful" risk-based safety program called SUBSAFE (24). Since the launch of SUBSAFE, not a single US submarine has been lost.

Another "heavy" industry, the nuclear power industry, has used risk management methods for the development of new regulation. Following the Three Mile Island disaster of 1979, John G. Kemeny delivered a report on behalf of the Presidential Commission entitled The Kemeny Report. Just as the Robens Report had done for the UK's coal industry, the Kemeny Report suggested the need for a major change in the nuclear industry's attitude towards health and safety. The report recommended that the industry move towards self-policing to promote its own standard of excellence, while criticizing complacency in the United States Nuclear Regulatory Commission. Over the next few decades, risk-based management systems became the standard for the nuclear industry. The NRC developed the probabilistic risk assessment (PRA) plan in 1994, a risk-informed performance-based regulatory framework which has since evolved into the risk-informed, performance-based (RPP) plan in 2007. These plans have guided the NRC in its efforts to develop risk-informed regulation, or risk-based governance. This regulatory approach helps the NRC identify and support additional requirements or regulatory actions, while reducing unnecessary requirements found in purely deterministic approaches, like prescriptive regulation. These regulatory requirements don't necessarily mandate risk-based approaches for occupational safety hazards, but they are designed to ensure that there is a low probability of accidents that could adversely affect the health and safety of the public (10). The safety success of risk-based approaches in these highly hazardous industries undermines the notion that accidents are inevitable and are the price of productivity in inherently dangerous industries like coal mining.

Perhaps the most pertinent example of the successful implementation of risk-based governance in a heavy industry can be attributed to the Australian minerals industry. The Australian minerals industry began its movement towards risk-based management systems following two mine disasters: the Moura coal mine explosion of 1994 and the Gretley coal mine inundation of 1996 (11). The industry subsequently identified the capability of risk analysis methods to mitigate key hazards like fires, explosions, spontaneous combustions, etc. The varying state-controlled regulation that followed generally requires mines to regularly perform some style of risk assessment to prevent circumstances which may result in occupational injury or fatality. Mine managers are also expected to demonstrate competency in risk management systems through training and certification (13).

This shift to a risk-based approach saw the development of National Codes of Practice and Mining Design Guidelines (MDGs) in lieu of more prescriptive legislation. These codes of practice retain bodies of knowledge – using a "may" rather than a "must" ideology – to promote flexibility in each mine's approach towards risk. Regulators commission these codes of practice through collaboration with representatives from the industry, unions, and the Australian mine inspectorate (a 'tripartite' body). Enforcement of Mine Operators is focused on system failures rather than minor infractions. Essentially, if a Mine Operator (in Australia) can legally establish that their risk management system equals or exceeds the standards proposed by Codes of Practice and MDGs, they cannot assume liability for incidents, promoting best safety practice. A failure to fulfill these obligations will result in prosecution of the operator. This methodology is an improvement for the individual miner, and focuses on what operators can control. In the case of an accident, recklessness (MSHA citation form 7000-1 uses the term gross negligence) must be proven, which limits overreaction of legal responses – particularly the promulgation of reactive legislation.

In the years following the adoption of a risk-based safety culture, Australia saw a drop in the number of fatal accidents at underground coal mines which was proportionally superior to the drop seen in the US for the same time period (*Figure 2*).

It is worth nothing that although the Australian metaliferous industry enacted "duty-of-care" legislation in 1994, a major drop in fatalities in this sector did not occur until several years later when risk management approaches began to see more application and maturity (13). During the five-year period between 2006 and 2010, there were 20 times more fatalities in the US coal mining industry than in the Australian coal sector to produce only twice the volume of coal (21). The general downward trends in Australian underground mining fatality rates have been, in part, attributed to the industry acceptance of and obligation to employ risk-based management systems towards its safety goals. While risk-based governance has contributed largely to the Australian experience, it is unclear whether or not risk-based approaches would have been so rapidly adopted by companies without being mandated. Further, it has taken years of continuous improvement and extensive cooperation to develop today's acknowledged mutual respect among the mine inspectorate, the mining industry, and its labor force ('tripartite governance') with respect to implementation of OHS risk management.

There are limitations to all approaches. Risk management is not necessarily a "catch all" solution to preventing incidents, but an optimization of human well-being and overall system performance. Risk-based management systems provide guidelines for how risks are to be managed, who is responsible for implementing actions, what resources are required, and the level of training required to properly implement the plans. These systems also identify the monitoring and review requirements necessary to maintain the system's effectiveness and relevance. Risk management is a balance of preventing failures and promoting positive outcomes.

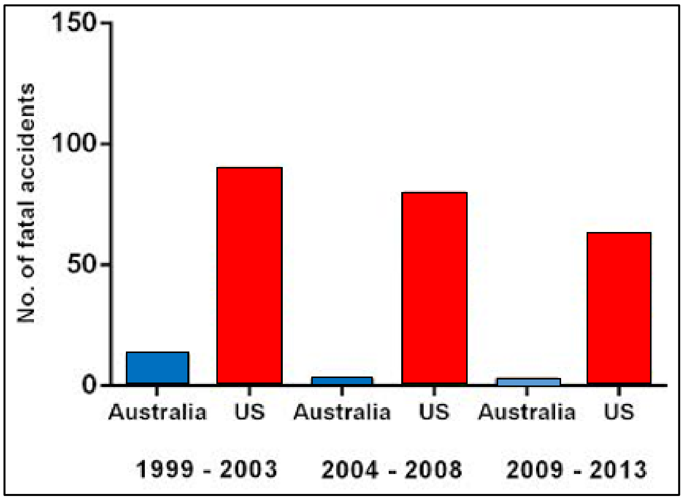

Figure 2. Number of Fatal Accidents in Underground Coal Mines for Australia and the US[1].

So what has prevented the widespread adoption of comprehensive risk management systems by US coal mining companies? Yang (2012) provides evidence of several barriers which have hindered the diffusion process of risk management in the US coal industry (34). One potential barrier is the historical lack of a perceived "common fate" among various coal mining organizations operating in the US (large versus small). Although the recent reoccurrence of major disasters has sparked an emerging recognition of common fate throughout the industry, reputational concerns still vary greatly across the diversely scaled operations of the US. Australia's industry reform was largely influenced by the consolidation and acquisition of small coal mining operations by larger corporations – there are currently only 33 underground coal mines in Australia's major coal producing regions, compared with 488 in the US (2, 21). The lack of small, low-production operations in Australia contributes to the industry's general acknowledgment of common fate among all stakeholders, including mine operators, the government, and labor unions. The Australian coal market is also export-driven, while the US consumes the majority of its coal products domestically – approximately 93% of total coal production in 2012 (34). The Australian coal industry is more integrated with the international coal market, and due to increasingly tough competition from low cost, high production coal-exporting nations like China and India, and the large contribution of coal products to the state's GDP (9% versus less than 0.5% in the US), the Australian coal mining industry has seized the opportunity to establish itself as a global leader in mine health and safety performance (34).

Strict, prescriptive regulation and enforcement thereof with high-cost penalties and citations, is another barrier to the diffusion of risk management and adoption of best practices in the US. US company compliance with these regulations consumes company resources which could be utilized to develop a risk management framework, or explore other health and safety models which might better suit their organization's needs. Costly penalties for violations have a particularly profound effect on the capacity of small-scale operations to invest in research and development of new safety models that go above and beyond what is required by law. As Yang points out, "such regulation creates a compliance mentality that is not compatible with the idea of risk management, which expects operators to proactively identify, analyze, and control hazards" (34). A competing safety model, behavior-based safety (BBS), is an additional factor restricting the diffusion of risk management in the US coal industry. Yang (2012) attributes the widespread US adoption of the BBS model to several key factors when compared to a risk management approach. These factors include a focus on worker performance for individual tasks, a "bottom-up" worker-driven thrust based on peer evaluation and employee feedback, and the observable benefits which include an improved safety culture and an increase in knowledge sharing from lessons-learned discussions between employees and management (34). Additionally, as BBS rises in popularity and more expertise is developed for the BBS process, these observable benefits become more apparent, the incentives for alternative (risk management) systems appear less appealing to mine operators, and the entry cost for a novel system (risk management) is much higher than a broadly adopted or accepted approach.

PRELIMINARY RESULTS AND RECOMMENDATIONS

In 2011, the Australian Coal Association Research Program (ACARP) initiated the development of an interactive online risk management tool called RISKGATE (18, 19, 21). Designed through the collaborative efforts of multiple coal mining experts and coal industry practitioners, RISKGATE provides operators with a body of knowledge containing current best practice information regarding risk identification, assessment, and management in the coal industry. RISKGATE provides users with customizable checklists for preventative and mitigating controls dealing with an array of principal mine hazards identified by the Australian coal industry. Currently, RISKGATE is only available to the Australian coal industry, which funds the project through ACARP.

In 2013, the Alpha Foundation for the Improvement of Mine Safety and Health funded a research proposal for an examination of how risk management principles can be applied in a comprehensive manner to the US underground coal mining industry to improve mine safety. This project is the joint effort of researchers from Virginia Tech and researchers from two Australian Universities (University of New South Wales and University of Queensland) whose contributions were integral to the development of the Australian RISKGATE tool. A central aim of this research is the development of a US-based online risk management tool that adapts the RISKGATE body of knowledge to assist US mine operators. Unlike RISKGATE, this tool will be available to the public with no associated fees, and will focus on only three underground coal hazard topic areas: fires/explosions, strata (roof) control, and collisions. Ease of access looks to be a key feature of the tool, which will promote industry use even if only supplemental to existing safety programs.

Several action research workshops have been conducted with the help of several US coal industry players. These workshops were facilitated by the research participants, and attended by US mining practitioners who included frontline workers, safety officials, and technical experts, among others. These initial workshops have focused on the identification of risk controls specific to US operational standards, along with applying appropriate and necessary alterations to the existing Australian RISKGATE body of knowledge, including differences in language and terminology (e.g. goaf versus gob). Already, discrepancies have been identified between Australian and US standardized control measures. For example, the use of proximity detection systems is recommended as a control to prevent collisions between persons and moving equipment in RISKGATE AU, but is now required by law for certain equipment (continuous miners) in the US. However, proximity detection technology is considered immature by Australian standards, and is not yet mandated. For example, the Australian RISKGATE body of knowledge contains the following caution statement at the start of information about management of collisions: "At the current state of development in the mining environment, collision management systems (CMS) are insufficiently robust to prevent interactions between mobile equipment. Here, 'collision management system' (CMS) is an umbrella term that includes both proximity detection technology (PDT) and collision avoidance systems (CAS). Proximity detection technology actively scans for other vehicles, infrastructure or personnel and warns of their presence but

[1] The data in this figure was collected from publicly accessible documents made available by the Mine Safety and Health Administration (MSHA) and the Australian Bureau of Labor (ABS) for analysis, with findings to be disseminated in a future publication.

does not automatically take action to prevent a collision (e.g. simply triggers an alarm). In contrast, CAS makes use of various technologies to actively scan for other vehicles or personnel and take automatic action to render the equipment to a safe state (e.g. slowing or stopping the vehicle) (28)".

The knowledge gathered at these workshops is being used to refine the tool's development process. Future developments include a pilot study of the completed RISKGATE US tool to demonstrate US application of both the tool and the risk management approach, and a subsequent analysis of the study with consideration to the entire mining sector including surface coal and non-coal operations.

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