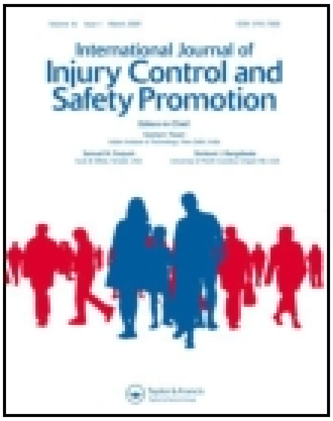

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The causes and control of loader- and truck-related fatalities in surface mining operations

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Abstract

At surface mining operations throughout the world, loaders and trucks are a primary means of material loading and haulage. As the size, use and technological complexity of these units have increased, so has the concern regarding loader and truck safety. The severity and number of accidents involving loaders and trucks is higher when compared to all other mining accident types. In this paper, an analysis of loader and truck-related fatalities over the last 8 years is performed, the fatality categories and causes of accidents are established and control strategies are discussed and evaluated in an effort to increase hazard awareness by emphasizing safe loading, hauling and maintenance practices, as well as the value of traditional and innovative miner training programmes.

Keywords: Trucks, loaders; fatalities; causes and control; mining; safe practices; training programmes.

Introduction

The mining industry is a vital economic sector of the USA and includes exploitation of coal, metal and non-metal minerals. According to the US Department of Energy,[1] Mine Safety and Health Administration (MSHA)[2] and the National Mining Association[3] there are nearly 1,500 surface and underground coal mines, 200 metal mines and nearly 11,700 aggregate production (stone, gravel, sand, etc.) operations. Almost 270,000 people work directly in mining through the production, preparation, processing, development, maintenance, repair, shop or yard work. The use of minerals by nations worldwide is extensive and includes, but is not limited to, electrical generation, production of cement, steel, agricultural lime, commercial and residential building products, asphalt and medicines, as well as countless household, electronic and other manufactured products.

During the period 1900 to 1990, the number of mining fatalities and the fatality incidence rates decreased significantly.[4] This remarkable downward trend has continued during the last decade, as the number of non-fatal injuries and illnesses within the mining industry has also declined. Of the 5,900 total work-related fatalities that occurred in 2001, only 72 (1.2%) were mine-related. Coal mining accounted for 0.7% and metal and non-metal mining 0.5%.[2] Figure 1 shows the total number of injuries for coal and metal and non-metal mining that has occurred from 1990–2001, while Figure 2 shows the total number of fatalities from 1990–2002.

The average number of injuries for the period was 9,935 in the coal sector and 11,250 in the metal and non-metal sector. The historical record of injuries continues to show a significant decline. The data for coal and metal and non-metal mines indicate a total of 1,188 fatalities for the 12-year period from 1990–2002, an average of 99 per year. Unfortunately, the decline in the number of fatalities is not as significant as the decline in the number of injuries, although the number of fatalities dropped from 90 to 67 (the lowest number of mining fatalities ever recorded) during the period 1999–2002.[2]

Despite the record of progress that has been achieved in reducing mining fatalities and injuries, both the number and severity of mining accidents occurring are still unacceptable. Most significant and of concern is that the fatality and serious injury rates have reached a plateau.[5] Continued improvement of miners' safety and health requires a two-pronged attack on

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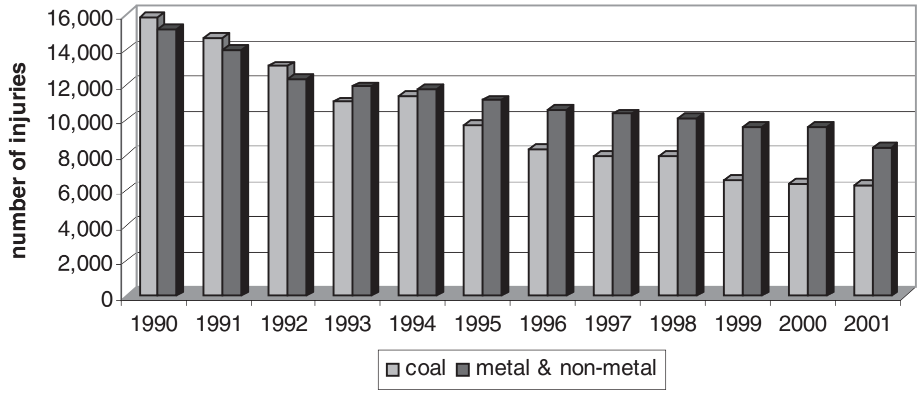

Figure 1. The total number of injures in mining.

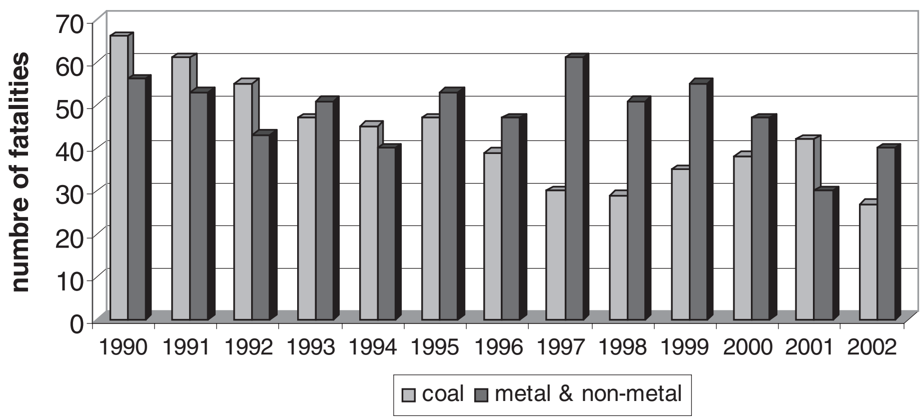

Figure 2. The total number of fatalities in mining.

accident causes, one that is fundamental and traditional (i.e., the three Es of engineering, enforcement and education) and one that is more innovative and creative (e.g., applying behavioural principles and technological advances to better control and eliminate hazards). The two approaches are synergistic. The efficacy of the attack will not be obtained from one or the other, but rather from the application of both simultaneously. Planning, as well as programme and policy implementation must be followed by regular monitoring and control activities. Future mine health and safety progress requires the systematic planning of appropriate safety programmes and measures. The safety management decisions that must be made to select and prioritize problem areas and safety system weaknesses must be based on the recognition of hazards encountered in each activity of the mining process. Based on the available reports, the highest number of fatalities is related to powered haulage, e.g., the motion of powered haulage equipment, such as wheel loaders, haul trucks, conveyors, forklifts, shuttle cars and hoisting equipment.[2] Among these, the greatest proportion of fatalities is related to wheel loaders and haul trucks. To address this issue, a research study was undertaken and an analysis of loader- and truck-related fatalities over the last 8 years was performed, the fatality categories and causes of accidents were established, the design and evaluation of activities that have to be taken to prevent hazards are discussed and the implementation of effective programmes and policies is described.

Analysis of loader and truck fatalities

The data for mining operations indicate a total of 121 fatalities involving wheel loaders and haul trucks for the 8-year period from 1995–2002. Figure 3 shows the number of fatalities per year, while Figure 4 shows the number of fatalities per type of mining operation. A total of 32 loader-related fatalities occurred over the 8-year period, an average 2.66 per year and 89 truck-related fatalities, an average of 7.41 per year. There were 34 loader-related fatalities in coal mining, 21 in metal and 66 in aggregate production.

Loader-related fatalities

Based upon the MSHA accident investigation for each of the fatalities,[6] the authors of the paper have established a categorization of accident type, root cause and additional contributing factors. These categories include: (i) collision with

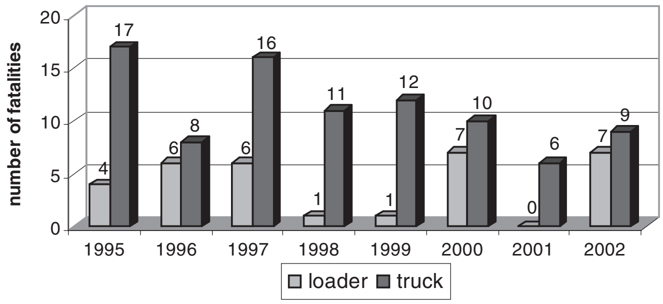

Figure 3. Number of fatalities involving loaders and trucks.

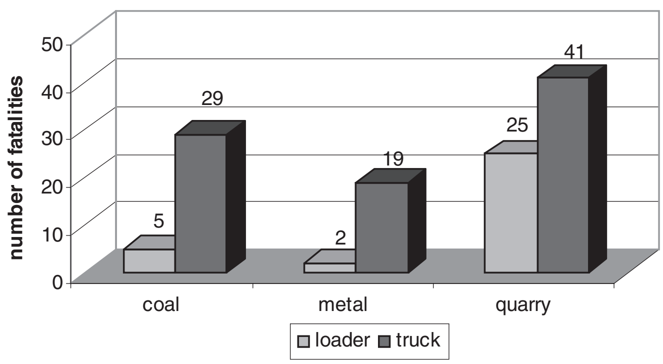

Figure 4. Number of fatalities involving loaders and trucks per type of mining operations.

pedestrian; (ii) rollovers; (iii) equipment repair; (iv) contact with public utility lines; and (v) slope failure (Figure 5).

The percentage distribution of each category of loader-related fatalities is shown in Figure 6. Incidents where mine and non-mine personnel were hit, struck or run over by the wheel loader are the most common and represent 41% of the total loader-related fatalities. The second highest proportion of fatality incidents (34%) involved 'rollovers' from the elevated edge of the pit, haul road, waste dump or elevated stockpile ramp. The proportional distribution of the remainder of the fatality incidents were as follows: equipment repair and/or replacement of the bucket, motor or tyre, 13%; direct contact between the loader and high pressure, public utility natural gas transmission lines, 6%; and bench or high-wall slope failures, e.g., where a miner was buried by sloughed off material (rock, sand and gravel, other overburden), 6%. In 19 of the 32 fatality cases, the loader operator was the victim.

Based upon an analysis of the MSHA accident investigation reports, the root causes are established as shown in Figure 7. These causes are classified in eight categories and include: 1) failure of mechanical components; 2) inadequate maintenance procedures; 3) failure to recognize adverse geological conditions; 4) failure to respect the loader's working area; 5) failure to maintain adequate berms, i.e., the barriers on the outside edge of haulage roads, or ledges within the mine wall slopes that must be left for safety reasons; 6) lack of warning signs and appropriate mine maps; 7) inadequate provisions for secure travel; and 8) failure to adjust to poor weather conditions.

Failure of mechanical components involved inadequate or defective braking systems (e.g., parking or service brake) and the failure to identify and correct the cause of engine stalling. This category represented 28% of the loader-related fatalities. Inadequate procedures during maintenance included the practice of allowing personnel to perform maintenance from the elevated bucket of a loader, management's failure to establish procedures that required blocking the mobile equipment against hazardous motion before performing work on it, allowing miners to use an inadequate method (poorly field-fabricated and damaged) to support the loader arm frame assembly and bucket, the failure to block the bucket assembly against hazardous movement, failure to examine the equipment prior to use, altering equipment in a manner that affected access to the parking brake, failure to remove or properly block the front-end loader fender prior to installing the wheel assembly, failure to provide the bucket and lift arms with load-locking devices, failure to completely deflate the tyre and remove the valve core assembly before working on the wheel assembly and the failure to follow manufacturers' written recommendations. This category also represented 28% of the loader-related accidents.

Failure to recognize adverse geological conditions represented 17% of the fatalities. It included the mine operator's failure to detect, recognize and/or take appropriate measures regarding an adverse geological condition in an active highwall mining area, management's failure to design and construct the roadway and dumping facilities with materials capable of supporting the loads to which they were subjected and failure to maintain a safe distance from the unstable bank of the pit and waste dump.

The failure to obey or respect the loader's working area caused 9% of the fatalities. It included events where the loader operator did not notice pedestrians around the loader, unauthorized entry into the loader's working radius and the failure to provide warning signals that the loader was backing up. Failure to maintain adequate berms along the elevated edge of the roadway above the pit and failure to identify the narrow work area as a hazard caused 6% of the fatalities.

Contact with public utility lines represented 6% of the fatalities. Warning signs or other devices were not in place to indicate the exact location of gas lines in relation to the work area. Additional illumination was not provided in the area where work was being performed in close proximity to the line. The mine map available to all management personnel and posted at the mine office did not indicate the most recent location of the gas line. The lack of a provision for secure travel while training was being conducted represented 3% of the fatalities. Poor visibility due to a heavy rainstorm is categorized as weather conditions and also represented 3% of the fatalities.

Further analysis revealed several contributing factors to these fatalities, which are categorized as: the lack of adequate

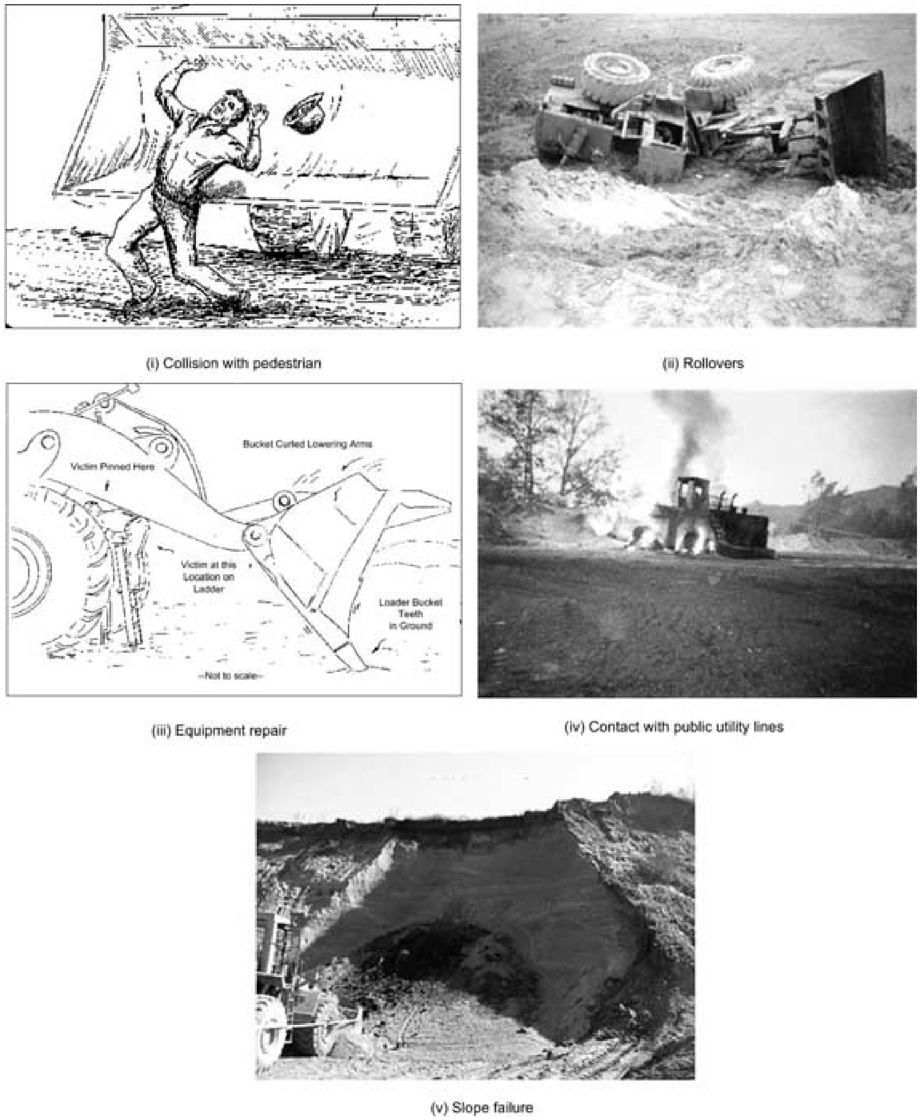

Figure 5. Basic categories for loader-related fatalities (drawings and photos are used by permission of Mine Safety and Health Administration).[2]

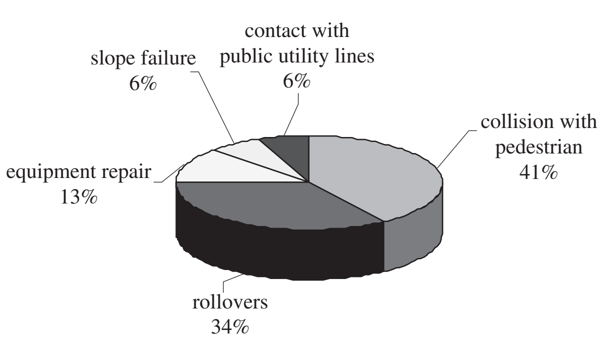

Figure 6. Proportion of loader fatalities to total fatalities by category.

training (37%); the failure to wear seat belts (31%); lack of efficient communications (19%); and the failure to maintain the haul roads (13%).

Truck-related fatalities

The truck-related fatalities are shown in Figure 8 and include: (i) rollovers; (ii) direct collision with a pedestrian; (iii) collision with another vehicle; (iv) equipment repair; (v) contact with public utility lines; and (vi) other.

The proportional distribution of each truck fatality category is shown in Figure 9. Incidents involving ‘rollovers’ from the elevated edge of the pit, waste dump or elevated haul roads are the most common and represent 47% of the total fatalities. The second highest proportion of incidents (28%) includes fatalities when mine and non-mine person-

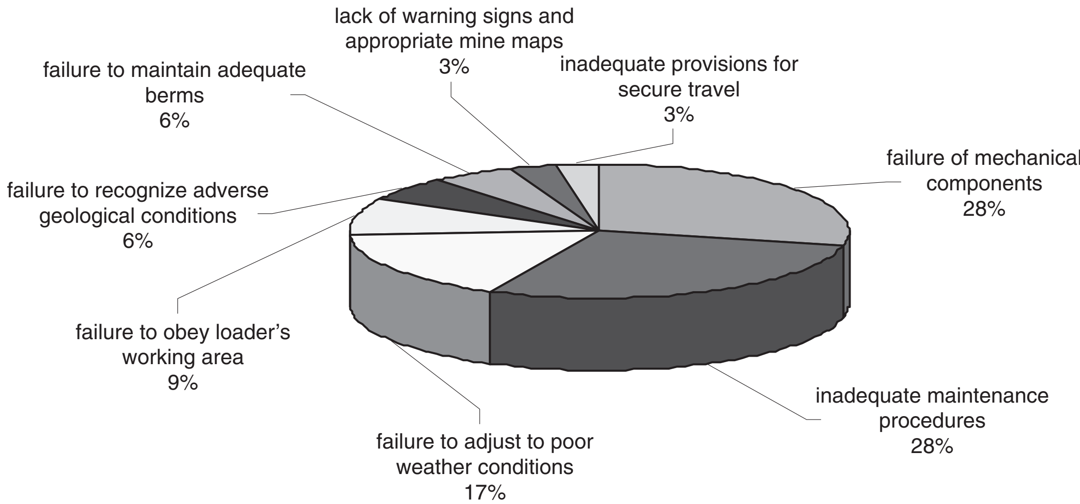

Figure 7. Root causes of loader fatalities.

nel were hit, struck or run over by the truck. The proportional distribution of the remaining fatality categories are as follows: direct collision between trucks and other vehicle, 11%; equipment repair, 8%; direct contact between the truck and high-voltage power lines, 3%; and 'other', 3%, which includes incidents of a truck fire, a truck that collided with the rock berm along the edge of the roadway and where a truck driver died while operating the truck.

Based upon an analysis of the MSHA fatality accident reports, the root causes are established as shown in Figure 10. These causes are classified in nine categories and include: 1) failure of mechanical components; 2), lack of and/or failure to obey warning signals; 3) failure to maintain adequate berms; 4) failure to recognize adverse geological conditions; 5) inadequate hazard training; 6) inadequate maintenance procedures; 7) failure to respect the truck's working area; 8) failure to set the parking brake; and 9) operator's health condition.

Failure of mechanical components includes the brake systems, engine stalling, defective power take-off control cable, damaged steering, transmission and engine, air leaks on the truck, a corrosive environment, the transmission linkage, the electrical retarding system, the gear selector control cable, a hydraulic line, a ruptured hydraulic steering hose and a sticking accelerator linkage. The primary causes of these fatalities were failure to properly maintain the truck's mechanical components and a failure to establish procedures requiring that safety defects be reported, recorded and promptly corrected. This category represented 22% of the total truck-related fatalities.

Lack of and/or failure to obey warning signals accounted for 20% of the fatalities. The primary causes of these accidents were the failure to maintain adequate clearance between the overhead power lines and the mobile equipment that was operating near the stockpile, the failure to use effective means to warn the victim prior to movement of the haul truck, the lack of direct communication between the truck driver and the victim, failure to use the headlights, inadequate warning signs regarding narrow roadways, narrow bridge (including 'no passing') and poor visibility, insufficient illumination in the work area, management's failure to establish effective traffic control for the safe movement of mobile equipment, failure to follow established rules governing traffic control for the safe movement of mobile equipment at the mine, failure to stop at the railway crossing and yield to the train, ignoring traffic control rules and failure to obey the posted speed limit.

Failure to maintain adequate berms along the elevated edge of the pit and waste dump and failure to identify the narrow work area as a hazard caused 13% of the fatalities. Failure to recognize adverse geological conditions accounted for another 10%. This category includes the mine operator's failure to detect, recognize and/or take appropriate measures regarding an adverse geological condition in the high-wall mining area, management's failure to design and construct the roadway and dumping facilities with materials capable of supporting the loads to which they were subjected and failure to maintain a safe distance from the unstable bank of the pit.

Inadequate hazard training of the truck's operator caused 10% of the fatalities. The causes of these fatalities were insufficient pre-job briefing and practice in the task under supervision, lack of procedures to ensure safe work practices, failure of the company to ensure that safety policy was followed, failure to establish a safe method to distribute material in the loaded trailers of over-the-road trucks, lack of working experience and the failure of management to enforce the use of the safety belt and line restraint system when drivers were positioned on top of the tanker trailer units performing work.

Inadequate procedures during maintenance included failure to secure the raised bed of the truck prior to per-

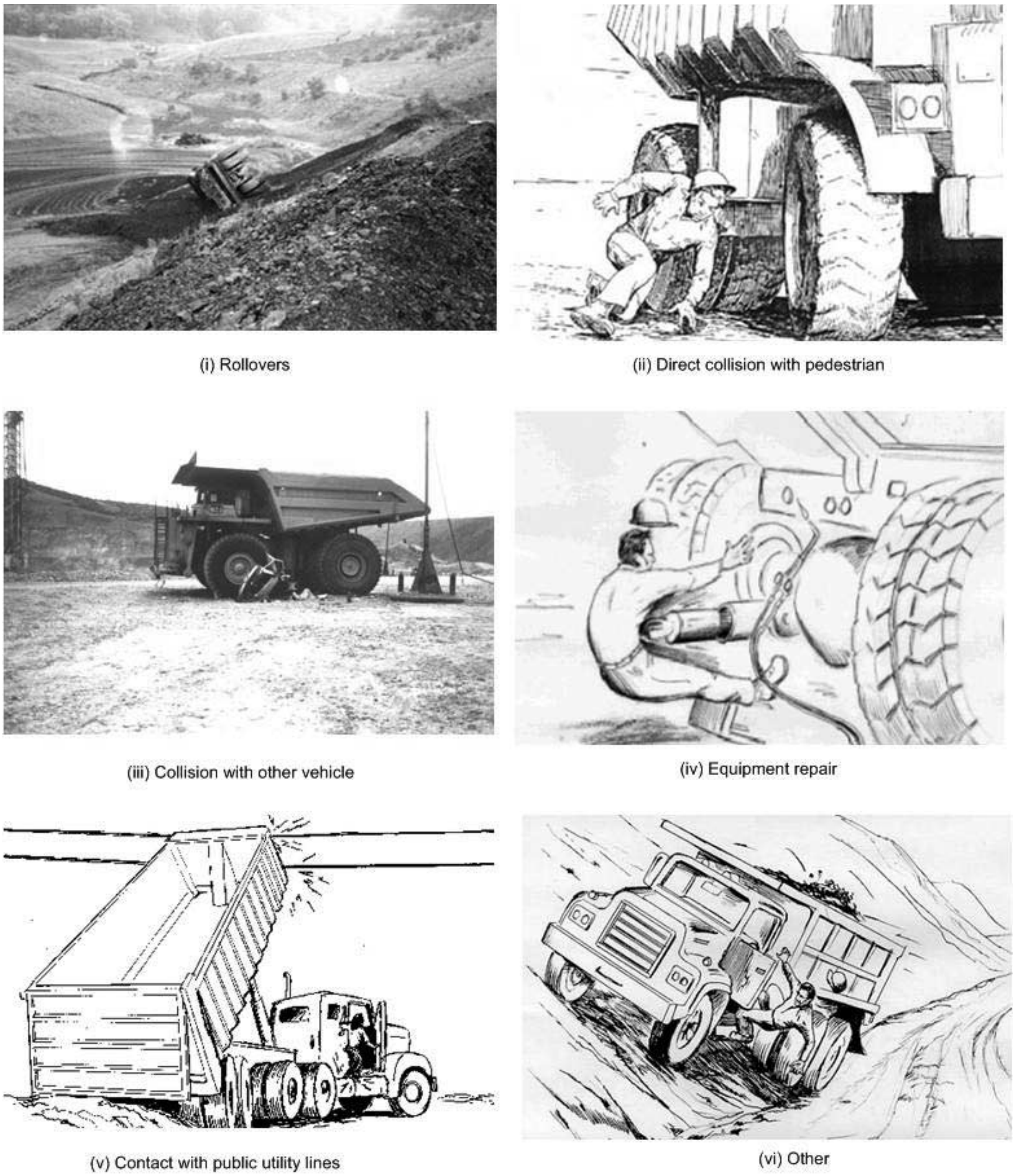

Figure 8. Basic categories for truck-related fatalities (drawings and photos are used by permission of Mine Safety and Health Administration).[2]

forming work under it, failure to block the truck against motion while performing maintenance work under the vehicle, performing work in a hazardous position beneath the truck between the axle and an improvised metal stand and performing work from an elevated position without wearing a safety belt and a safety line. This category represented 7% of the truck-related fatalities.

The failure to respect the truck's working area caused 7% of all truck-related fatalities. This category includes at-risk practices such as the driver's inability to account for the victim while backing the truck, the unsafe location of the victim, the failure of the victim to stand clear of the truck, which he had been spotting, coupled with the failure of the truck driver to observe the location of the spotter prior to backing up the vehicle and parking a utility truck too close to the haul truck.

Failure to set the parking brakes before the driver got out of the truck accounted for 7% of all truck-related fatalities. Finally, the operator's health condition was the direct cause of 4% of the truck-related fatalities. This category includes both management's and the operator's inability to determine the extent of the pre and existing health conditions. This category also includes fatalities caused by driving under the influence of alcohol.

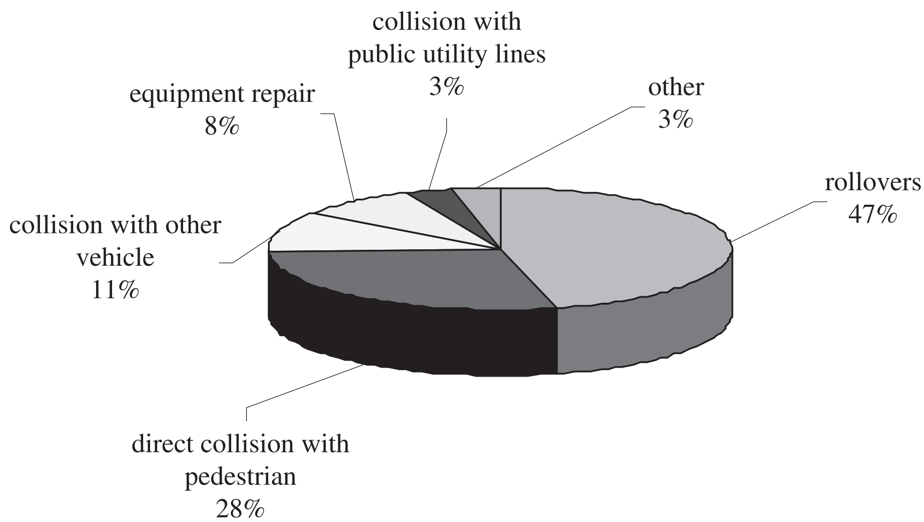

Figure 9. Proportion of truck fatalities to total fatalities by category.

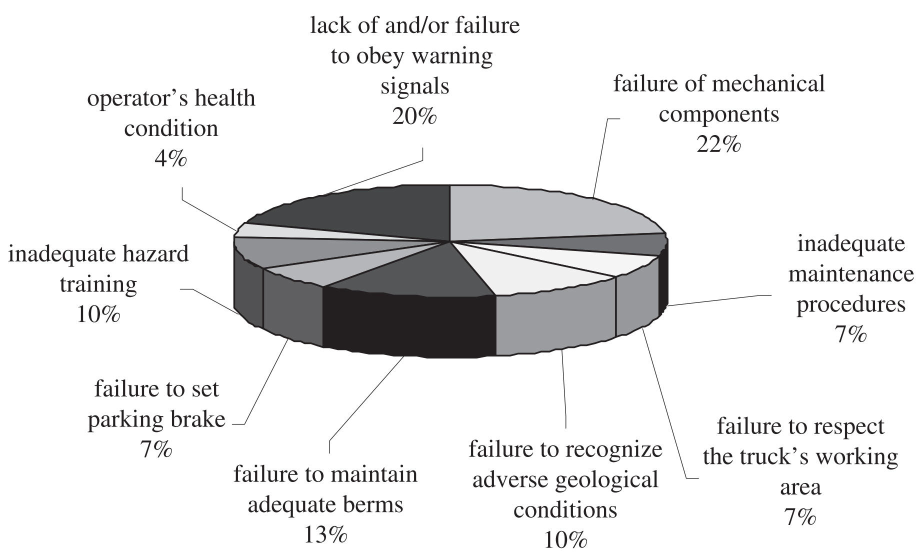

Figure 10. Root causes of truck fatalities.

Summary of analysis

This analysis of recent loader- and truck-related fatalities has illustrated the seriousness of the problem of powered haulage for mine management, miners, government regulators, trainers and safety consultants. Powered haulage, like mining itself, is inherently dangerous and the causes of the related accidents are complex, encompassing management planning, monitoring and control activities, as well as issues such as commitment to safe production, design and engineering, safety standards, enforcement of standards, training and safety behaviour. For example, the failure to wear seat belts whilst driving was the primary contributing factor to several of the truck-related fatalities. Seat belts are a form of personal protective equipment and their primary purpose is to limit the severity of injury in collisions and rollers. Wearing seat belts in trucks and loaders, if considered in isolation, appears to be a highly personal matter and one that is, incidentally, difficult to monitor. Yet it is an outcome of behaviour that involves several, if not all, of the aforementioned issues. The complexity of loader and truck safety demands a systematic problem-solving approach. The most important components of an accident reduction strategy for powered haulage safety are addressed in the remainder of this paper.

Consideration of prevention methods

Most accidents could be avoided by careful job planning, provided that there is a thorough understanding of what to do and how to do it. It should be emphasized that safety must always be the most important concern. MSHA has recently promoted the maxim that safety is a value. Mining companies must embrace this philosophy enthusiastically, articulate it in their mission statements and reflect it in their policies, decisions and monitoring and control activities. Management's commitment to safety must be transparent through its decisions and actions. Mine operators must have a commitment to safe production, since unqualified production easily lends itself to compromises in the relentless need to identify and eliminate hazards in a timely manner. Management must have a clear understanding of the work to be done, consider dangers or hazards, develop plans to do the job safely and then explain the plan to all concerned. Properly trained operators, knowledge of the work environment and a machine free of safety defects, play a critical role in preventing loader- and truck-related fatalities. The need for a comprehensive accident reduction approach is fundamental to reducing powered haulage fatalities and fatality incidence rates and includes, but is not limited to, compliance with regulations, safe practices, training and effective policies and programmes.

Mine Safety and Health Administration regulations

The first step in managing haulage safety is knowledge, understanding and enforcement of the pertinent government safety standards for surface powered haulage (Title 30, Code of Federal Regulations (CFR), Part 56 and 77).[7] The standards are quite comprehensive. Most of the relevant standards for loader and truck safety for surface non-coal operations can be found in Part 56, Subpart H (Loading, Hauling and Dumping) and Subpart M (Machinery and Equipment). The standards in these subparts encompass, but are not limited to, safe operating speeds, necessity of adequate berms, safety of truck spotters, unstable ground and dumping locations, horns and back-up alarms, correction of safety defects, adequate brakes and tyre repair. Several standards in Subpart B (Ground Control) are also relevant, such as those that prohibit work activity between a machine and a high-wall toe and the requirement to inspect ground conditions and mitigate any related hazards that may be present. The majority of the safety standards pertinent to loader and truck safety in surface coal operations are found in Subpart Q (Loading and Haulage) and Subpart E (Safeguards for Mechanical Equipment). The standards related to loader and truck safety in these subparts cover, but are not limited to, standardized traffic rules, signals and warning signs, restriction of unauthorized persons on haulage roads or at dumping/loading locations, adequate brakes, equipment inspection, recording of and correction of defects, de-energizing machinery and blocking prior to repairs, safe operation (e.g., maintaining a safe distance between vehicles), berms, audible warning devices, unattended vehicles, operating speeds, seat belts and the establishment of communication (by signal or other means) between equipment operators and pedestrians. Loader and truck operators working in surface coal mines also need to be familiar with the requirement to examine high-walls, banks and benches and to avoid dangerous high-walls and banks (Subpart K – Ground Control). The following safety practices must also be considered and consistently followed.

Safe practices

The failure of mechanical components, particularly the brake system, was the main cause in loader- and truck-related fatalities. Today, loaders and trucks are equipped with at least three distinct brake systems: service; emergency; and parking. Many machines are also equipped with a retarding brake system. It is of crucial importance that the operator fully understands the function and limitations of these individual brake systems as well as how and when to use them. Before loading and haulage operations, brake systems should be tested to ensure that they are operational and capable of stopping the equipment. Any deviation from normal operations must be corrected immediately. Regularly scheduled examinations should be conducted and the equipment must be maintained to the original equipment manufacturer's specifications. Equipment should not be left unattended unless the controls are placed in the park position and the parking brake is set, and when parked on a grade, the wheels of the equipment should either be chocked or turned into a bank.

Loader and truck operators must read and understand the operator's manual and the safety instructions and signs on the equipment; operators must determine that the machine is in proper order before operating. The operators must be alert, physically fit and free from the influence of alcohol, drugs or medication that might affect their sight, hearing and reaction. The operator has almost complete control of these safe practices.

The adoption of safe work procedures, which incorporate manufacturers' recommendations, are essential in ensuring that workers are not exposed to hazards when performing maintenance or repair work. All maintenance and repair personnel must be trained in standardized procedures for their tasks. Prior to beginning work, the working area must be clear of trip and fall hazards, safe access to all work areas should be provided and appropriate fall protection must be used where there is a danger of falling. Equipment should be locked and tagged, secured against movement prior to repair work and personnel should stay focused on their job tasks at all times.

Berms, haul roads and traffic patterns should be designed to minimize the chances for operator error. Also, berms should be established and maintained along elevated roadways and around water hazards, which meet or exceed MSHA requirements. Mine management should enforce rules governing the direction of travel, right of way and use of headlights. Additionally, haul roads should be maintained in a manner conducive to safe travel, equipment should be operated at speeds compatible with road and weather conditions, signs warning equipment operators of road hazards and safe speeds should be posted at all approaches and equipment should be operated in lower gears conducive to safe travel on steep grades. Equipment operators should wear seat belts whenever the vehicle is in motion.

In order to avoid fatalities that result from not respecting the loader and truck working area, the following basic safety rules should be implemented: require drivers and equipment operators to remain in their units while in designated areas; prohibit foot traffic in loading and haulage areas; develop a communications system to alert equipment operators with restricted visibility to pedestrians and other traffic in the area; provide signs that clearly describe traffic hazards on mine property; require loader operators to visually confirm that truck drivers are in their cabs before loading; and ensure that equipment operators proceed cautiously when entering areas with tight clearance or areas where personnel are present.

Hazardous geological conditions should be recognized by both mining management and equipment personnel. Dumping locations should be inspected prior to work commencing and material should be dumped back from the edge where the ground is unstable. Berms or impeding devices should be installed at dumping locations to prevent overtravel. Dumping facilities should be constructed of materials capable of supporting the loads to which they will be subjected. An adequate on-shift examination should be conducted of all high-wall conditions. The approved ground control plan should be followed at all times to ensure the safe control of all high-walls. The appropriate mining methods should be adopted that will maintain wall, bank or slope stability in all work areas. Waste material with a high percentage of fine particles in a saturated condition can develop excess internal water pressure that reduces the stability of the pile. When signs of instability are present, material should be dumped at a safe distance from the edge.

Excavation and loading should not be done near subsurface gas transmission lines without knowing exactly where the line is located. Mine maps shall be kept up to date to reflect any changes in the location of gas transmission lines and well locations.

In the case of restricted visibility due to inclement weather, equipment operators should turn on all exterior lights and keep the cab windows free of condensation or other obstructions that affect visibility. Signs or signals that warn of pedestrians should be installed where persons routinely cross plant roadways on foot. Operating speeds should be consistent with conditions of the roadway, visibility and possible pedestrian traffic. Equipment operators should keep buckets, forks or booms close to the ground when travelling.

Following safe practices in the operation, maintenance and repair of powered haulage equipment depends on knowledge of the safe practices and job procedures and an effective training programme to teach and maintain the skills among an ever-changing workforce.

Training

Mining industry stakeholders have long recognized training as a critical element in effective health and safety programmes and the attainment of safe production.[8,9] Of the many forms of training in use today, three general types can be identified: 1) skills training; 2) management training; and 3) motivational training. Skills training is used mostly to address skill and knowledge gaps in worker-machine interactions. Management training focuses on worker–worker and worker–idea relationships. Examples of common management training topics might include time management, decision-making, human relations, communications, etc. Motivational training seeks to influence worker attitudes and beliefs.[10] Taken together, federal regulations (30 CFR, Part 48, Part 46, Part 56 and Part 77) mandate a comprehensive programme of health and safety training, which, it can be argued, provide several forms of skills and motivational training. Parts 46 and 48 contain only training regulations and address the training needs of new miners (e.g., new miner training), experienced miners (e.g., annual refresher and newly hired experienced miner training), miners engaged in a new task (e.g., task training), as well as training for contractors (new miner, newly hired experienced, annual refresher and/or hazard training, as appropriate) and visitors to the mine property (e.g., hazard training). To ensure effective training programmes, companies must develop approved training plans and use certified or competent persons to conduct and evaluate the training. Parts 56 and 77, Health and Safety Standards – Metal and Non-Metal Mines and Mandatory Health and Safety Standards – Surface Coal Mines and Surface Work Areas of Underground Mines, respectively, contain several standards for the training of qualified and certified training and supervisors.

Mandated miner training focuses on establishing a comprehensive knowledge among the workforce of safe practices and a hazard avoidance mentality, as well as maintaining that knowledge and mentality and passing on new skills and knowledge as the need arises. Effective training is always structured and systematic. Any structured training programme should follow a five-step process that consists of the following phases: 1) analyse the problem; 2) design the training programme; 3) develop the training materials; 4) implement the training; and 5) evaluate results of the training.[11] During the first phase, needs assessment is conducted to diagnose any performance problems and propose the training intervention. Figure 11 describes a process to determine trainability and can be a useful tool during this initial training phase. Use of this flowchart is especially appropriate in determining the cause of substandard performance associated with the powered haulage incidents described in this paper. According to the flowchart, performance problems may be non-trainable, i.e., caused by systemic problems not related to skills, knowledge or motivation. Incidentally, motivational problems are somewhat unique in that they can be addressed through a training intervention, but are more likely

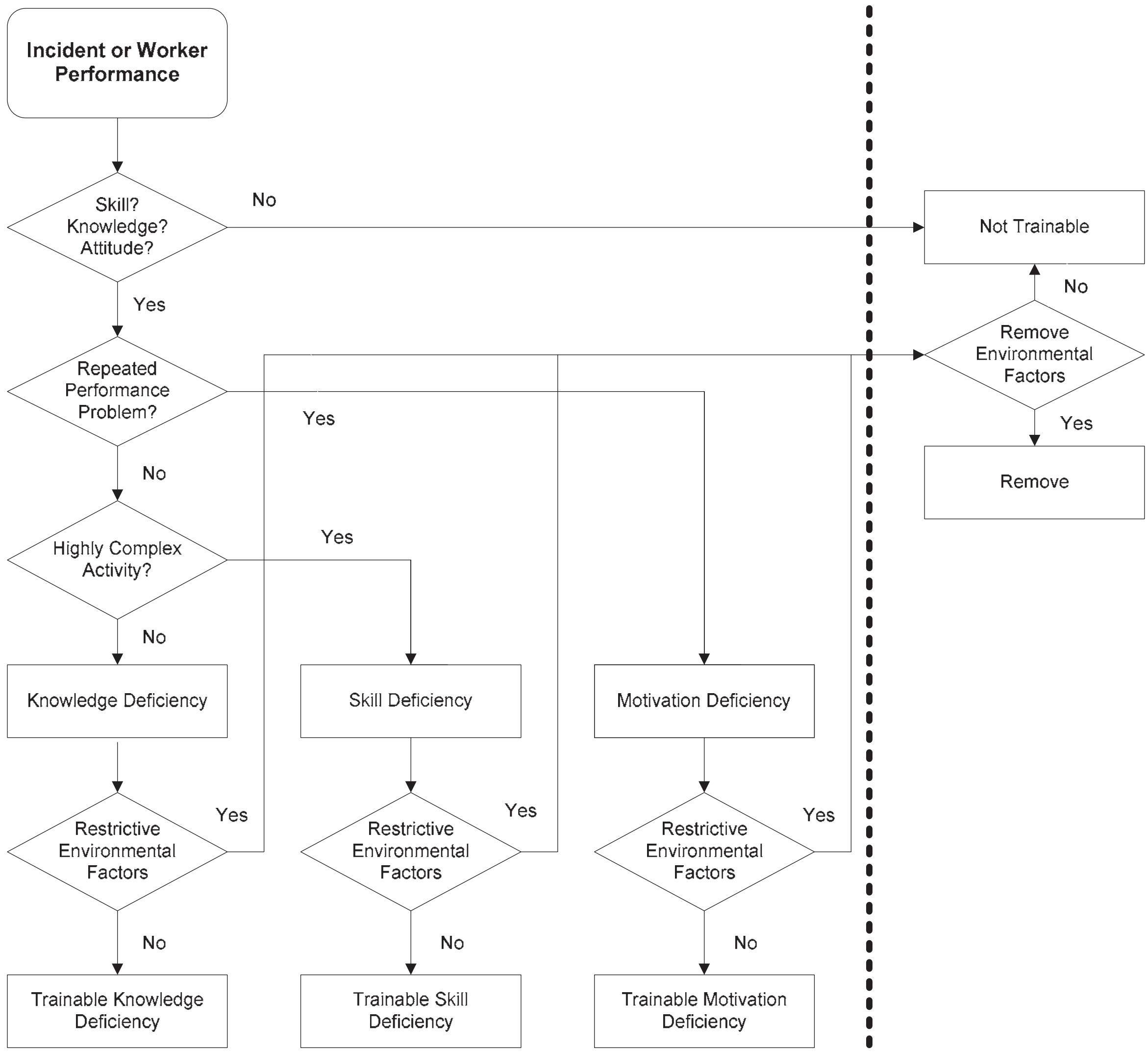

Figure 11. Flowchart for trainability analysis (source: Adapted from Bise *et al*.).[18]

caused by reward structures, supervision or other job factors. The subsequent phases of a structured training programme are self-explanatory. Training professionals are continuously seeking better ways to improve miners' training.[8]

The latest developments in virtual reality (VR) have resulted in major opportunities for improving the safety training of mine workers, supervisors and managers.[12] The application of VR to improve the effectiveness of skills training for powered haulage operators, especially the anticipated influx of new miners in the coming years, is promising.

VR-based training simulators can be used to train experienced and novice operators in the basics of driving, loading, tramming and dumping skills in a safe, highly visual and interactive learning environment. One example of VR-based operator training is the Fifth Dimension Technologies 5DT wheeled loader and haul truck training simulator.[13] The main advantage offered by these simulators, in addition to effective training, is safety. Novice operators can learn the necessary operator skills without the fear of causing potential losses (e.g., injuries and property) that may be faced in traditional 'hands-on' operator training, where an actual loader or truck is used (Figure 12). Various loaders and truck manufacturers have also developed training simulators that expose the operators to various simulated events, such as darkness, rain, congested work areas, etc. An example of a Caterpillar training simulator[14] is shown in Figure 13.

Implementation of effective policies and programmes

MSHA has established the minimum requirements for safety programmes in surface metal and non-metal and coal mines. The standards can be found in several subparts within 30 CFR, Part 56 and Part 77 (Part 56, Subpart Q – Safety Programmes, Subpart N – Personal Protection, Subpart S – Miscellaneous and Part 77, Subpart R – Miscellaneous). Subpart Q requires operators to: 1) designate a competent person to examine working areas at least once each shift for

Figure 12. Loader and truck training simulators (images courtesy of Fifth Dimension Technologies).[13]

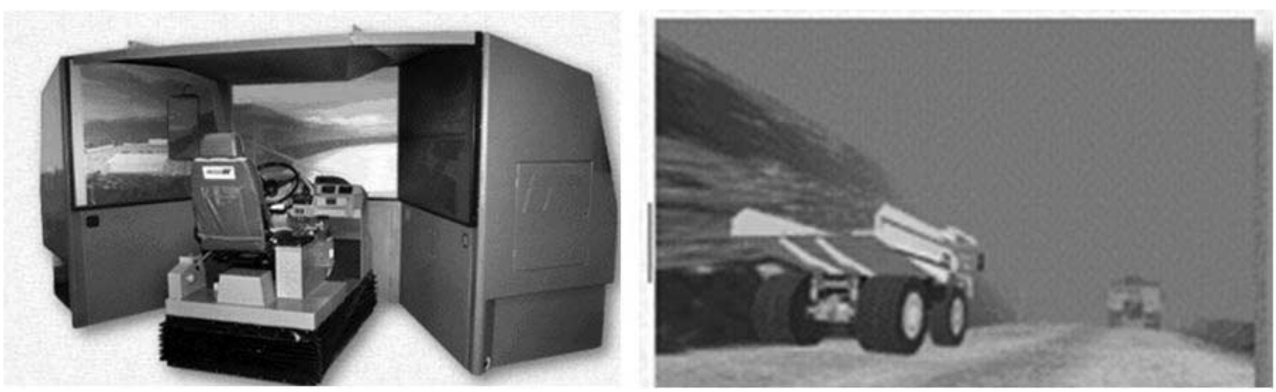

Figure 13. Caterpillar truck training simulator (images courtesy of Caterpillar).[14]

hazards, document findings, correct unsafe conditions and withdraw miners if an imminent danger is found; 2) indoctrinate new employees regarding safety rules and safe work procedures; 3) designate a competent person to take charge in case of emergency; 4) have at least one individual available on each shift who can provide first aid; 5) post emergency numbers at appropriate telephones; 6) maintain an emergency communication system; 7) make prior arrangements for obtaining medical assistance for injured persons; and 8) not assign, allow or require employees to perform or work alone in any hazardous area unless they can communicate with others, can be heard or can be seen. Subpart N includes standards for first aid supplies and personal protective equipment, such as hard hats, protective footwear, eye protection, protective clothing, safety belts and lines, etc. Subpart S covers, but is not limited to, the use of intoxicating beverages and narcotics in and around mines, housekeeping and barricading/warning signs where subtle hazards exist.

Part 77, Subpart R includes similar versions of the standards contained in Part 56 with regard to working alone, communications, emergency preparedness, first aid training, first aid equipment, a programme of instruction in safety regulations and procedures, inspections of the work areas and protective clothing. In addition, 30 CFR Part 50 requires that each operator investigate each accident and each occupational injury.

It can be argued that MSHA's standards on powered haulage safety, the training standards and the standards described above represent a comprehensive strategy or sufficient policies encompassing enforcement, engineering and education approaches to significantly reduce or eliminate loader- and truck-related fatalities. In fact, the MSHA regulations encompass the critical activities that comprise a loss control programme, except for the activities of hiring and selection, engineering and purchasing controls and group communications.[15]

In mining, or any industry, safety is not solely a question of compliance with government regulations. There are at least three good arguments in support of this statement. First, regulations often represent a minimum safety standard and, in some cases, such as MSHA's regulation allowing safety belts for personal fall protection, represent a less than adequate standard. Second, it has also been argued that the pursuit of safety should be motivated by a desire to improve the worker's quality of work life, rather than by a desire to please government regulators by avoiding a citation. Finally, a comparative analysis of several accident prevention approaches found that government action (e.g., regulations, inspections and accident reduction information dissemination) ranked fifth behind behaviour-based, ergonomics, engineering change and group problem-solving in its ability to reduce injury rates.[16]

The fact that powered haulage accidents continue to claim the greatest proportion of mining fatalities indicates the need to investigate new accident prevention approaches that will supplement the three Es of enforcement, education and engineering.

Behaviour-based approaches (BBS) to loader and truck safety programmes appear promising and should be considered. The approach is theoretically grounded in learning principles and behavioural science methods and has been used successfully in the mining industry to improve worker safety performance.[17] This BBS process charges work groups to identify safety-related behaviours, assess the workforce in terms of those behaviours, provide feedback on performance and remove environmental barriers that may prevent the implementation of safe practices.

Mine operators who are experiencing powered haulage safety issues and past problem (incidents, violations, etc.) may want to consider creating a position of 'powered haulage supervisor', who would be responsible and held accountable for operator training, equipment inspection and maintenance programmes, haul road and dump engineering design, etc. The role would be one of monitoring and control to make sure that the standards in each of the areas mentioned are adequate and are being followed. While this may seem to be a luxury, especially in lean economic times, it appears as though many companies cannot afford to ignore such a focused approach to such a critical mining operation as powered haulage.

Conclusion

Despite significant decreases in both the number of fatal mine accidents and fatality incidence rates over the last century, the level of recent progress in injury reduction has reached a plateau. A persistent area of concern in mine safety continues to be powered haulage. Based on the number of fatalities per year, powered haulage represents the most dangerous aspect of surface mining. Of the various types of powered haulage accidents, the most common are loader- and truck-related. An analysis of these incidents for the period 1995–2002 reveals that the most common types are collisions with pedestrians and rollovers, while the most common root causes are failure of mechanical components, lack of and/or failure to obey warning signals and inadequate or substandard mechanical procedures. In addition, several key contributing factors, such as inadequate training, poor haulage road and dump design engineering and the failure to wear seat belts were associated with several powered haulage accidents. Because of the small number of cases that occurred in the period cited, these findings and conclusions should not be associated with powered haulage accidents in general.

The complexity of powered haulage safety demands a systematic accident prevention approach, which incorporates both traditional as well as innovative loss control measures and programmes. Mine management must adopt a 'safe production only' mentality that is driven by a 'safety is a value' philosophy. Management loss control activities must include a thorough knowledge of and strict compliance with government safety and training regulations. In addition, safety management must encompass a comprehensive system of planned activities for the control of hazardous conditions and the adoption of safe practices in operational and maintenance activities. These outcomes can best be achieved through vigilance to the traditional three Es of safety and the adoption of innovative programmes such as behaviour-based safety, VR-based training simulators and more focused monitoring and control for haulage operation activities, such as oversight by a dedicated powered haulage supervisor.

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