
**CRITICAL TECHNOLOGIES FOR ORGANIZATION AND
MANAGEMENT**

A common thread throughout our discussions was the importance of good operations management to success in a very competitive market environment. Mining is not unique: Since the 1980s, efforts to improve management (epitomized by benchmark companies such as General Electric and Intel) have been undertaken throughout the business community. Improving mine organization and management practices has the potential to greatly impact productivity, staffing patterns, health and safety, and even the layout of mine and quarry operations.

Unlike hard-technology solutions, the critical management and practice innovations cited by study participants tended to be unique to each company or operation. Areas of technology-related management innovation range from a focus on the individual to reorganizing the operations of an entire site and include

- Outsourcing of important mine tasks
- Health and safety
- The human environment
- Technology and human-resources management

OUTSOURCING

Our discussions revealed that while fundamental changes in unit-ops technologies in the coming years are likely to be rare, the way in which mining equipment and services are being acquired, operated, and maintained is changing dramatically. Mine activities that commonly are outsourced include drilling and blasting operations, equipment-performance and regulatory-compliance monitoring, warehousing, and maintenance and repair. On the other hand, the outsourcing of an entire mine operation—commonly referred

to as contract mining—while frequent in the industry, was not looked upon favorably by our discussion participants.

Outsourcing of maintenance and repair was noted by many participants in the technology discussions as an industrywide trend. Maintenance agreements vary considerably and are influenced by the size of the mine unit and the availability of off-site maintenance facilities and personnel. But increasingly, mining companies are shipping components or entire pieces of equipment to suppliers or maintenance and repair specialists off-site instead of supporting a comprehensive maintenance operation and performing major repairs on-site. This outsourcing can be further enhanced by transmitting equipment diagnostic data directly to manufacturers, service contractors, and parts suppliers, allowing maintenance actions to be scheduled, parts ordered, personnel notified, and production operations modified automatically. The development of such a remote-service infrastructure has been facilitated by improved logistics and transportation to mines (particularly in the western United States) and is beginning to be used by all segments of the industry. More comprehensive O&M contracts entail providing dedicated personnel on-site along with the necessary equipment and are typically used by large operations with heavy maintenance burdens.

Benefits of outsourcing that participants cited include

- Lower O&M labor costs
- Lower maintenance-facility and overhead costs
- More-predictable maintenance expenditures
- The ability to obtain the necessary capabilities at mines where they are not locally available

An additional advantage of outsourcing, according to a technology provider, is that mining companies often can draw on the know-how accumulated by specialists from operations both within and outside mining (e.g., engine or lubricant manufacturers). Finally, by moving maintenance functions off-site, mining companies can ease their regulatory-compliance burdens.

Some participants mentioned disadvantages and impediments to O&M outsourcing: small mine-unit size, managing the logistics of several maintenance contractors operating on-site, lack of convenient service personnel and facilities off-site, mistrust of contractors or the feeling that they are not members of the “mine team,” and questions of union acceptance. An exception to the trend toward contract maintenance is found in the underground coal-mining sector. One participant with broad industry experience noted that the coal producers prefer to cross-train their operators to run equipment and repair it themselves.

A motivation for this is flexibility: In a mine with a single longwall panel, for example, a breakdown must be repaired immediately.

As outsourcing develops, some mining companies are focusing on core competencies, while others are developing new lines of business.

- A coal-company executive cited warehousing as one of his firm's top three cost centers and reported efforts to "push everything back to vendors" to reduce on-site warehousing requirements and inventory overhead through just-in-time parts delivery.
- In response to the greater use of mobile crushers across the aggregates industry, one aggregates firm has made efforts to develop a major capability in overhauling mobile crushers so that it can provide this service to other firms as a separate line of business.

THE HUMAN ENVIRONMENT

Assuring the health and safety of mine workers was an important concern of the study participants, and many noted that health and safety figure prominently in their statements of company objectives. Many mining executives claimed that their operations exceeded regulatory requirements for health and safety and also exceeded average industry performance.

When asked to identify critical health and safety technologies, many operating-company representatives focused on personal protective equipment and innovations they or their organizations had pursued.

- All personnel at one firm's underground coal mines are required to wear reflective safety vests—a measure described as "a simple but effective" way to reduce injuries.
- In collaboration with a glove manufacturer, a coal company developed and deployed Kevlar-reinforced, padded metacarpal work gloves after observing a high incidence of injuries due to pinching and abrasion. The gloves "significantly reduced" the severity of hand injuries.
- A communications company has deployed a warning system in which the miner's radio is integrated with the helmet-lamp battery. In the event of an emergency, a warning signal triggers the lamp to begin blinking. The miner can then respond, providing instant confirmation of his or her location and status.
- A large metals producer developed its own catalog of recommended personal safety equipment, with an emphasis on low-tech, wearable solutions, including gloves, respirators, and air hoods.

Drivers of enhanced health and safety efforts cited were risk management (e.g., avoiding lawsuits and litigation), reducing lost worker time, improving produc-

tivity, maintaining morale, and common sense. Complying with health and safety regulations appeared to be a secondary technology concern. For example, when asked to identify critical innovations for mining health and safety, discussants rarely mentioned compliance technologies.

Rather, they typically pointed to what they saw as innovative personal safety equipment or programs their firms had undertaken on a voluntary basis that went beyond regulatory requirements. For instance, a coal-company representative reported that his organization replaced the ladders on its loaders with steps, which were seen as safer and more user-friendly. Another coal company expressed its interest in obtaining a new earmuff technology that monitored and recorded ambient and transmitted noise levels, allowing a quantitative assessment of effectiveness.

Several of the study participants noted that injuries in mining are increasingly resulting from human errors rather than equipment failures or geologic factors. Consequently, in conjunction with improving equipment and environmental safety, the mining community is emphasizing the importance of safety through behavior modification. In an effort to reduce strains and sprains, a coal company encourages its workers to stretch for 15 minutes before a shift. Two firms reported the implementation of companywide accident-reporting systems to benchmark performance across all of their units (regardless of the type of mining) and identify problem areas. Another firm implemented an accident- and violation-reporting program in which memos discussing accidents as well as rule infractions not resulting in injury are circulated to all company personnel.

In many cases, efforts to improve health and safety entail behavioral and practice innovations rather than technical solutions.

- An international company has developed a companywide safety index composed of four criteria measures, two of which are changed every month to keep the effort fresh.
- Under the motto of “creating safe workplaces and caring for the individual,” the management of a major surface mine periodically observes the work of rank-and-file staff at the job site and presents its findings through personal, informal communications. The observations (made by foremen as well as the company president) increase worker safety awareness, empower staff through the exchange of ideas and experiences, and help “break down the traditional labor-management hierarchy.”
- Management at a large surface mine has its haul trucks drive on the left side of the road to move the operators further from danger in the event of a collision.
- As part of an effort to improve ergonomic conditions in its underground operations, a major coal producer in the early 1990s instituted a program to observe and modify work practices and conditions. The program reportedly resulted in a reduced incidence of strains, sprains, and back injuries.

Underground mine safety is benefiting from improved geomechanical monitoring, said several industry leaders. Microseismic and rock-deformation sensors are used to monitor pillar deformation, roof sagging, and crack propagation; to identify unstable conditions; and to help predict dangerous occurrences of catastrophic brittle-rock failure (bumps or bounces). Several participants noted that these concerns are expected to increase as U.S. mines begin to operate at greater depths in the future.

The increasing reliance on O&M outsourcing, noted by many discussants, also can have important health and safety implications. For example, an operating company may elect to outsource blasting to reduce the risk to its employees. While this may appear to represent a displacement (or offloading) of risk, two technology providers argued that the outsourcing of blasting to specialist firms with specialized training and equipment and an organizational focus on blast safety was in fact a move to an overall higher level of safety. “Our people are trained better than anyone else in the world,” said one blast-services executive.¹



A video camera mounted on the front of a haul truck at a mine helps drivers see personnel and equipment in their vicinity.

¹Similarly, the advent of more specialists in lubrication and oil recovery and recycling in the industry is likely to lead to overall reduced exposures to hazardous materials.

In addition to identifying technologies developed and used specifically to address occupational health and safety, discussants pointed to the health and safety implications of emerging technologies. Two representatives noted that the increased size of mining equipment—trucks in particular—raises health and safety concerns about vibration, visibility, and braking. In response, a large surface mine operation has outfitted each of its 240-ton haul trucks with three video cameras: one in front, one in back, and one to the right (opposite the operator’s cab). Drivers use the cameras to scan for personnel and vehicles in their vicinity, as well as to position their trucks and monitor the dumping of material.²

Wheel-bearing-temperature indicators on haul trucks help operators avoid front-spindle failures. In a recent year, 40 trucks experienced such failures, with wheels coming loose on two occasions, reported one industry representative. Another posed the question of large-truck stability in case of a tire blowout. Devices that monitor tire pressure and temperature in real time are expected to reduce the incidence of blowouts, a source of occasional injuries and fatalities. Finally, two heavy-equipment manufacturers emphasized the importance of computer-assisted “fly-through” design tools that allow designers to virtually explore the operator environment, including visibility and access to controls, of potential equipment designs.

Mining-industry participants identified several promising technologies to improve health and safety that may be commercially available to the mining industry by 2010.

- *Vision assists.* Images generated using infrared sensors mounted on the front of a vehicle are projected in front of the operator. Such systems reportedly enable an operator to see four times farther at night and in poor weather.
- *Heads-up displays.* The technology to project control-panel information onto cabin windshields is being developed by the automotive industry and may be applied in mining vehicles as original equipment or as an aftermarket installation.
- *Proximity detectors.* Radar technologies for detecting nearby vehicles are reported to be in use at the facilities of two metals producers. The detectors “almost certainly” will be in common use by 2020, according to one discussant. Also under consideration are tags similar to theft-alert devices used in retail stores, which can detect personnel up to 50 feet away.
- *Voice-activated controls.* This technology currently is being developed by the automotive industry.
- *Biometric sensors.* In-cab imaging technologies are being developed that will monitor an operator’s eye and facial characteristics for signs of drowsiness.

²While praising the potential value of cameras, several discussants questioned the reliability and usefulness of current technologies in the harsh mine environment.

Many important mining-equipment innovations raised in the discussions not only mitigate health and safety risks but also address the need to create a more enjoyable, interesting, and productive work environment. This is clearly important, given the need to attract and retain highly qualified workers and to maintain high productivity while operators are on the job.

Many pieces of mining equipment for both underground and surface operations are being designed with enhanced overhead protection and enclosed operator cabins. Several operating companies and equipment manufacturers cited the benefits of cabins for reducing exposure to noise, dust, heat, and vibration. One executive pointed out that over the past 20 years, construction of operator cabs has improved significantly, with better sealing and the increased use of sound- and vibration-mitigating materials. Increased cab leg room was cited as a notable amenity by one machinery-supplier executive. Joystick control schemes are also being increasingly incorporated into equipment. When applied to excavators and shovels, one executive observed, such features can offer important productivity benefits, since shovel operators often are seen as a key determinant of productivity at open-pit mines.

New generations of mining equipment feature enhanced noise and vibration attenuation, climate controls, ergonomics, and operator visibility.

- New-generation excavators situate the operator above the operating area, affording 180-degree visibility as opposed to the 90-degree visibility in older models. Dual cabs in some models add greater operator flexibility.
- An equipment manufacturer has introduced a doubly articulated LHD unit, with the cabin located on the central section. In addition to adding flexibility for working in tight environments, the design includes specialized suspension and ergonomic features that reduce physical stresses on the operator.
- One large mine operation reported working closely with an equipment manufacturer on enhanced noise-dampening involving mufflers, exhaust-system positioning, and blanketing.

TECHNOLOGY AND HUMAN-RESOURCES MANAGEMENT

A common argument raised by industry executives was that despite the prospect of automation and other technology enhancements, people are becoming *more* critical to the success of a mining operation, not less. Several relevant arguments were put forth:

- As mining equipment increases in scale and staffing levels decline, individual operators play a greater role in determining mine output.

- The mining workforce is aging, making retraining of older workers a priority.
- Achieving the productivity gains sought by both management and investors requires empowering the rank-and-file and upgrading their roles from following rules to solving problems.

As we saw in Chapter Four, IT is changing the way mining equipment is being deployed and operated. As mining equipment becomes more advanced through IT and communications innovations (sensors, advanced computing power, GPS, remote controls, and operator assists), line workers will have unprecedented access to information and control over the equipment they are operating. To maximize the productivity-enhancing potential of such technologies, miners will have to hone their multidisciplinary and critical-thinking skills. Moreover, operating companies will need to find or build expertise in areas such as computer programming, communications, and electronics. And these skills and capabilities will have to be refreshed and updated regularly.

“We must learn to adapt faster and faster, or we won’t be able to stay in business. It will become increasingly important to make adjustments as close to the action as possible. Increasingly, supervisors and managers will focus their attention on providing information and knowledge so that employees can make the right decisions, rather than making decisions and directing employees’ activities.”

—*Mine manager*

Many operating companies and technology developers admitted that the interface between miners and IT needs to be improved. One technology supplier noted that it masks the complexity of its crusher control systems behind conventional, plain-looking control panels so as not to overwhelm operators. Another reported that the performance of his company’s IT application at mines often deteriorated a while after it was initially installed, yet human factors were rarely identified by mining companies as the cause. The usual thinking is, “It’s a computer, it should figure out the problem.” When asked to identify the leading constraint on his firm’s ability to boost productivity, one industry executive, effectively conveying the sentiments of several participants, declared flatly, “Getting people to think.”

Not surprisingly, many executives stated that miners were their most critical asset. Yet competing for, recruiting, training, and retaining highly qualified, multidisciplinary workers in a strenuous “bricks-and-mortar” occupation presents a major organizational challenge—despite the high wages characteristic of the

industry.³ A coal-industry executive lamented that technological innovation in coal mining in particular was lagging because “the coal industry does not attract high-caliber, Ivy-League people.” A manufacturer reported that the industry needed an additional 8,000 properly skilled people worldwide to maintain its machinery. Speaking on this point, a stone and aggregates executive reported that his organization faced a shortage of skilled workers and that this was having an impact on maintenance in particular. He worried that his equipment was “getting stretched out” as the firm attempted to keep up with growing demand.

“We see mines doing all kinds of things. It really comes down to the individuals in leadership positions. Technology won’t solve problems. It’s a combination of technology and people.”

—*Technology supplier*

In approaching the subject of critical technologies, several industry participants explicitly downplayed the importance of hardware innovations in determining performance outcomes. A participant who is active across the coal industry asserted, “Productivity increases are being accomplished through operational changes—it’s cheaper than the capital costs of technology.” A representative of a major technology supplier identified people’s attitudes and innovative mine processes as critical components of a successful mine, adding, “Technology is only one leg of a three-legged stool.” Explaining how he doubled productivity and cut output costs by 40 percent, another participant from the metals sector observed, “We did it not by buying new equipment, but by motivating the workforce.” He added that even when a new technology may be useful, building acceptance and a commitment to use the technology to its greatest extent (“getting people fired up”) is an essential prerequisite to successful implementation.

In 1999, a major operating company adopted a business process-redesign program modeled after similar efforts at General Electric. The goal of the program is to “engage and energize” the workforce to improve productivity. The effort entails the formation of task forces to reexamine the effectiveness of all the company’s operations and activities and to assess how they are integrated. A company manager described the goal of the program as “getting people to think, and then getting them to think together.” The challenge of such corporatewide reengineering was not only that of improving productivity in a period of unprecedented competitive pressures, but also that of getting people to dedi-

³In 1997, mining employees earned the highest wages of all U.S. industry worker—nearly \$44,000 per year, compared with an average of \$29,000 for all industries.

cate themselves to mining in a new way in an age when the value of the industry in the United States has been open to question.

Several industry representatives noted that new-technology introductions require “buy-in” from the rank-and-file to be effective.

- At one facility, management introduced wireless radios to enhance communications in the mine, but workers resisted their use because of concerns about intrusive management oversight. Workers frequently failed to turn their radios on or reported that they were in “a noisy area.”
- A representative from a research institution reported that prototype remote controls that he had installed on a company’s mining equipment were summarily removed with an axe.
- Preventive maintenance requires that operators shut down and repair a piece of equipment well before a failure occurs. This can be seen as unnecessarily disruptive and threatening to immediate production targets. “Changing the way we’ve done it for the last 40 years,” said one executive, “requires selling the program to the people.”