Mining Executive Series

Using autonomous equipment to achieve high performance in the mining industry

Is there a benefits case for broader adoption?
We define autonomous mining equipment as equipment that does not require a person physically on the equipment or to remotely control its operation. Automated mining equipment operates via a programmed routine or is centrally controlled, with relatively few people overseeing the operation.

The significant advancements in industrial technology affecting automated equipment have provided a great opportunity for mining companies to achieve high performance. By installing technology within mining equipment, companies can often improve productivity, reduce cost, improve safety and access environments that might not be possible when equipment is under human operation—helping mining companies solve some of their most pressing business challenges.

The technologies are not new to the mining industry, as equipment manufacturers have been incorporating more advanced technological systems and components into their platforms. Already manufacturers have seen improvements in their autonomous equipment’s return-on-investment, mine efficiency and yields.

The transition to autonomous equipment has been a gradual one, as autonomous trucks and other equipment have been tested for more than a decade, and remote or autonomous equipment—such as loaders—are not uncommon in some underground applications. However, the broad use of autonomous equipment in mine sites has yet to become a reality, even though various companies have “automated” parts of their operations. To make the necessary transformational changes, companies need to not only automate but also change the way they design their operations, manage the business and their people, and integrate their technologies. Before mining companies can make this change, they must answer first the basic question of whether autonomous equipment will help them achieve high performance.

Accenture has been working with a number of mining organizations to better understand the potential impact of autonomous equipment in mine sites and what it would mean to their business. In 2008, a major mining equipment company asked Accenture to help them evaluate the autonomous mining market opportunity. We identified the market opportunity and its major drivers, and determined the potential economic impact for different autonomous equipment applications.

Through this evaluation, we found real, possibly substantial, economic benefits for mining companies. The dynamics of deposits and demographics are increasing the potential value for autonomous equipment. While we expect mining companies to deploy more autonomous equipment within the next decade or so, early adoption will continue to be a select group of companies with a high risk tolerance and ample financial resources.
Drivers influencing mine operators’ consideration of autonomy

Accenture spoke with mining companies to understand their perspective on future industry trends and their expectations for autonomous equipment (see Figure 1). While we heard a wide range of views on the potential benefits of autonomy, and when, or if, it would experience wider adoption, mining companies saw major challenges in deploying the technology and integrating it into their existing operations.

The mining industry is confronted with a number of well-known systemic challenges, including limited availability of qualified labor (both local and expat), remote and difficult work environments and the unending need to improve yields and reduce costs to meet competitive challenges in an industry where there is limited pricing differentiation.

According to our research, the three areas in which autonomy could provide the most value were in improving overall mine performance, increasing safety and reducing the aggregate labor requirements.

**Performance**

Autonomous equipment should operate more predictably. With less direct operator control over trucks, dozers and other equipment, inherent operator-induced variations in speed, load and travel as well as downtime, should be dramatically reduced. As a result, equipment could more frequently operate closer to desired parameters, such as making loads more consistent and reducing idle times, stockpiles, wear, and bottlenecks throughout the production value chain, etc., and yet still allowing an element of flexibility when conditions change. This improvement in equipment performance should directly improve mine productivity and yields.

In addition to reducing direct labor costs from fewer equipment operators, more precise and consistent equipment operation can reduce other operating costs. Mining companies may experience cost reductions due to less equipment wear and tear and fewer mishaps. Without human operation, equipment availability and utilization rates should rise, with no downtime needed for shift changes, operator considerations or unplanned maintenance. Overall, these cost efficiencies can reduce capital expenditures over a mine’s existence. In addition, energy costs should be lower per unit of production, as equipment
would operate closer to technical design with each cycle.

**Safety**

The use of autonomous equipment is expected to reduce safety-related events simply through the elimination or significant reduction in operator presence on equipment. Common challenges such as operator fatigue or judgment errors that lead to accidents could cease to occur.

The safety improvement implications should be even more critical in more dangerous and difficult locations of new deposits. By reducing the number of equipment operators, autonomous equipment can help make mining sites in these harsher locations more productive and economical.

**Skilled labor constraints and costs**

The persistent supply-demand labor imbalance—in both developed and emerging areas—has raised the cost of available skilled labor. Wages have risen over the past decade in response to difficulties attracting and retaining skilled resources; in remote locations, employee infrastructure costs such as housing have risen, as have training costs and other employee-related costs such as travel and necessities. Correspondingly, the rising cost of labor has improved the value proposition for autonomous equipment.

If equipment fleets could become autonomous, it would substantially reduce the direct labor force and support staff.
Economics of autonomous mining

Using the research findings and our mining industry experience, we set out to quantify the benefits for autonomous mining equipment and estimate the potential economic impact on the mine site. We created an economic model of an open pit mine and determined how the attributes of automated equipment would positively, or negatively, impact a site’s performance (Figure 2).

In our analysis, we evaluated the economics of three types of equipment that are candidates for open pit mine automation over time: trucks, dozers and drills. We segmented hundreds of active and potential future mines by considering the mine size, whether the mine is in a remote location far from any major population centers and whether it is located in a developed, transitional or undeveloped economy, thereby simulating 18 different mine types to represent the universe of potential mines and the application of autonomous equipment in each.1

This categorization allowed us to test each type of mine equipment in a range of potential operating environments.

**Autonomous equipment reduces costs**

Our findings show there is meaningful economic upside to deploying the equipment in autonomous forms (Figure 3). All major cost areas would be reduced, except potentially annual maintenance costs. Labor costs will likely experience the biggest proportional decrease since automation reduces the number of equipment operators by up to 75 percent. That decrease, among fewer pieces of equipment and reduced support facility costs with fewer employees onsite, would further reduce operator-associated costs, potentially achieving more than 80 percent in potential savings.2

Repair costs (defined as unscheduled maintenance) should also decline as improper equipment operation, damage from collisions, excessive wear and tear and similar issues would decline under the predictable operation of autonomous equipment. In operations with less skilled labor, repair costs tend to be even higher, and the benefit of reduced accidents would further decrease costs. Savings could range from 25 to 75 percent, depending on the existing operator skill levels.

The ability to more precisely control equipment performance and operational parameters...
Figure 2. Simplified mine economic model and autonomy benefit drivers.

<table>
<thead>
<tr>
<th>Financial levers</th>
<th>Financial drivers</th>
<th>Automation impact</th>
<th>Financial impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Productivity</strong></td>
<td>Machine run rate</td>
<td>Increases hours/day productivity at $X/ton</td>
<td>$X additional output</td>
</tr>
<tr>
<td></td>
<td>Downtime</td>
<td>Machines improve maintenance rating to X hours per 24-hour service</td>
<td>$X additional output</td>
</tr>
<tr>
<td><strong>Labor</strong></td>
<td>Operator</td>
<td>Remove X equipment operators from mine</td>
<td>$X labor savings</td>
</tr>
<tr>
<td></td>
<td>Maintenance/ support labor</td>
<td>Increase maintenance labor rates by X percent to address equipment complexity</td>
<td>$X increased labor cost</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td>Infrastructure costs</td>
<td>Remove of equipment operators decreases housing requirements by X percent</td>
<td>$X infrastructure savings</td>
</tr>
<tr>
<td></td>
<td>Annual equipment CAPEX</td>
<td>Mines invest in X equipment/year at an increased price of $X/equipment</td>
<td>$X increase equipment CAPEX</td>
</tr>
</tbody>
</table>

**Potential mine impact**

$X MM

Figure 3. Annual economic impact of autonomous equipment.

<table>
<thead>
<tr>
<th>Autonomous value levers</th>
<th>Trucks</th>
<th>Dozers</th>
<th>Drills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual operating expenses</strong></td>
<td>Operator labor (staff)</td>
<td>▼▼▼▼</td>
<td>▼▼▼▼</td>
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<tr>
<td></td>
<td>Maintenance cost</td>
<td>▲▲</td>
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<tr>
<td></td>
<td>Repair cost</td>
<td>▼▼▼▼</td>
<td>▼▼▼▼</td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td>Effective utilization</td>
<td>▲</td>
<td>▲</td>
</tr>
<tr>
<td></td>
<td>Operator efficiency</td>
<td>▲</td>
<td>▲</td>
</tr>
</tbody>
</table>

Note: Items in red shows decreased performance with autonomous equipment in use.
will help to reduce excessive equipment wear and damage.

In contrast, annual maintenance, scheduled repair and upkeep costs could rise moderately due to greater technical complexity of equipment and higher levels of electronic content (relative to existing equipment). This was considered a conservative assumption, given the possibility that the life-cycle maintenance costs could be reduced with equipment operating more uniformly, lowering cumulative wear during its useful life. Additional costs would arise from higher-salaried maintenance personnel, given the different skills required to maintain more sophisticated equipment.

**Improvements in productivity**

The productivity of a mine’s performance is determined by how many tons of material are moved per each piece of equipment (per year). In our evaluation, we quantified how the use of autonomous equipment can enhance productivity on two fronts—equipment utilization and operator effectiveness.

Equipment utilization is measured as the number of hours operated per year without operator-induced downtime. Autonomy would increase equipment utilization by reducing the number of hours idle, such as during a shift change, safety conditions or in other situations that can reduce the operator’s time for safely operating the equipment.

Operator effectiveness is measured by the tons an operator can move per hour. Operator-induced performance variation could be nearly eliminated by autonomous equipment. For example, if manual operator effectiveness is between 50 and 70 percent, the use of autonomous equipment could potentially raise that to the 90 percent range. This could result in equipment productivity increases of 20 to 40 percent.

1 We only evaluated the impact on open pit metal mines, and did not assess underground mines, mixed mines or open pit coal mines.

2 We considered the mine constraints end to end and the ramifications of autonomy on the downstream production processes. With higher output levels per unit of equipment (when operating autonomously), the mine site would use fewer pieces of equipment to achieve the same output. Alternatively, when deploying autonomous equipment, mines could boost output by allowing a mine to operate closer to planned performance. In our experience, we find mines often fail to achieve planned performance due to optimistic assumptions and inadequately considering actual historical performance experience.
Our analysis shows there are substantial potential economic benefits of autonomy for mining companies. As the technology matures and proves itself in an operating environment, mine operators that want to realize an economic edge will need to prepare to integrate these technologies into their current operations. Here are a few areas in which autonomy will impact long-established business practices:

**Miner operating model**
The value balance between technology and more traditional mechanical-centered operations will change. With high levels of technology, mine operators could oversee, monitor and even operate vast aspects of their operation from remote command centers. Operators will need to understand how to organize their operations differently, adapt their performance management approaches and rethink operational arrangements with vendors and service providers to effectively procure and deploy autonomous equipment.

**Service model**
Servicing for autonomous mine infrastructure and equipment technology requires more real-time analytics and a rapid response approach, with greater reliability rates and a higher uptime than current equipment mechanical systems. Gaining an understanding of how to integrate such a service model into site operations without significant risk is a mind shift that operators and service providers need to begin working on now.

**Capabilities**
The skills required to evaluate, procure, integrate, support and operate complex autonomous systems will be expensive to develop in-house. Not knowing the future technical demands at this early stage of development, forward-thinking operators should seek out vendor alliances to access the required knowledge and skills more quickly.
Technology integration

Autonomous equipment will require an integrated site technology infrastructure. With few autonomous technology standards around to develop this platform, mine operators will be stretched to manage disparate systems and need to begin understanding the complexities and possible solutions for their operations.

Increasingly, more companies are trying to do more for less (and, hence, do not spend much on new technologies), which may seem prudent in current times. However, if those companies wait too long, the technologies may become so integrated and the system so dramatically changed, they will find themselves with little time to adopt vast changes. Taking the time to develop an autonomous strategy and understand the business implications of that strategy now is necessary so operators can adopt the changes incrementally.

What this can amount to is demonstrated in this example: if a company wants to solve the challenge of improving truck productivity using autonomous trucks, a substantial change to mine operations will be needed. These changes could have a businesswide and/or site-specific impact on operating models. A mining company may need to adapt to the changes in maintenance (for example) of equipment and existing standard operating procedures and practices. It will require integrating, deploying and managing enabling technologies such as GPS, visual systems and complex equipment performance analytics. The mining company may then have to deploy maintenance teams differently with different skill sets. Such changes may require flexible thinking to acquire or outsource the requisite capabilities. This could be a tremendous change management endeavor reaching procurement practices, service and vendor-management approaches, performance management methods and spending priorities.

Autonomous equipment has the ability to help companies achieve high performance, but mine operators that shy away from making the necessary changes to integrate the autonomous equipment into the broader operation and business model will find limited success.
Contacts

Duncan Sloan
Managing director,
Accenture Mining industry group
duncan.sloan@accenture.com

Craig Savarese
Senior manager,
Accenture Corporate Strategy group
craig.m.savarese@accenture.com

Dean Brunicke
Senior manager,
Accenture Resources operating group
dean.brunicke@accenture.com

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