The mining industry is currently going through an adjustment from high to more moderate growth as China’s economy transitions from capital-intensive investment to a more services-oriented economy. The development of Chinese infrastructure created high growth and capital-intensive expansion in much of the mining industry from the early 2000s. We are now witnessing a renewed focus on productivity improvements and cost savings as planned expansions are completed.

This is not unprecedented. A similar transition occurred in the 1980s as infrastructure growth in Japan tapered. The difference this time is the role new technologies will play. In the last two decades communications, automation, robotics, data analysis, materials, biotech and energy technologies have advanced substantially, suggesting the industry could be on the verge of a dramatic increase in innovation.

Mining is an integral part of the global economy. The revenue of its top 40 companies is over US$700 billion, and according to some figures, drives over 45% of the world’s economy, directly and indirectly. It is the largest part of the economy in 70 developing countries and contributes over half (54%) of Australia’s export earnings and one-fifth (20%) of Canada’s. Mining companies have many of the biggest and most complex industrial operations in the world, drawing on suppliers and technology from every continent and undertaking many of the largest projects globally. Their technology and innovation groups should be amongst the most influential in the world through sheer spending power alone.

Despite the scale of the industry, innovation literature is generally more targeted at faster-moving industries with shorter innovation timeframes and lower capital requirements. We thought there was a gap, and within this context, VCI has set out to understand the state of innovation in the mining industry in 2014. The State Of Play survey aims to give an objective appraisal of the strengths and weaknesses of innovation in mining. This includes providing a picture of how the industry’s global innovation system works, what could improve it and how companies could improve their effectiveness within it.

Graeme Stanway, Partner VCI, November 2014
graeme@govci.com
## CONTENTS:
The report contains three sections, covering both the structure and delivery of innovation in mining:

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Chapter 1: Ecosystem</td>
<td>5</td>
</tr>
<tr>
<td>Shaping the Industry Innovation System</td>
<td>6</td>
</tr>
<tr>
<td>Innovation Roles for Key Players</td>
<td>8</td>
</tr>
<tr>
<td>Partnerships, Collaboration and Innovation Flow</td>
<td>11</td>
</tr>
<tr>
<td>Recommendations</td>
<td>13</td>
</tr>
<tr>
<td>Chapter 2: Strategy</td>
<td>14</td>
</tr>
<tr>
<td>Strategy Direction and Articulation</td>
<td>17</td>
</tr>
<tr>
<td>Innovation Focus</td>
<td>20</td>
</tr>
<tr>
<td>Strategy Development and Communication</td>
<td>22</td>
</tr>
<tr>
<td>Recommendations</td>
<td>24</td>
</tr>
<tr>
<td>Chapter 3: Delivery</td>
<td>25</td>
</tr>
<tr>
<td>Innovation Philosophy: Top-down and Bottom-up</td>
<td>27</td>
</tr>
<tr>
<td>Leadership and Culture</td>
<td>30</td>
</tr>
<tr>
<td>Technology Development Methodologies and Partnerships</td>
<td>31</td>
</tr>
<tr>
<td>Recommendations</td>
<td>35</td>
</tr>
<tr>
<td>Conclusions</td>
<td>36</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>39</td>
</tr>
</tbody>
</table>
INTRODUCTION
to VCI:

VCI is a global management consulting company that focuses on the resources industry. Our core focus areas are strategy, innovation, organisation and change. We work with senior leaders to overcome their most difficult and pressing challenges with a collaborative and open approach. VCI has built its reputation on the basis of a deep curiosity and applying creative methods to difficult problems.

This is our second annual survey and we have received over 230 responses from executives in the industry, of which 70% are at the C-level – including the chiefs of strategy, operations, technology and executive officers of many of the world’s largest mining companies and mining suppliers. The survey represents a broad cross-section of the industry with executives from 6 continents participating.

OUR SPONSOR

The Energy and Minerals Institute (EMI) at The University of Western Australia connects UWA’s talent and capability across the energy and minerals value chain, builds multi-disciplinary networks and strengthens partnerships with industry and external stakeholders. Guided by a Board of Trustees of key industry leaders, EMI provides strategic business development, governance, engagement and consultancy services across UWA.
Chapter 1: 
ECOSYSTEM

Focused on understanding how the mining innovation ecosystem works, including the roles of large and small miners, service companies, researchers and governments. Our recommendations focus on what is required for the system to work well and improve the level and quality of innovation in the industry.
CHAPTER 1: Ecosystem

The mining industry is reliant upon an ecosystem of suppliers, service providers, start-ups, research institutions, governments and asset owners as a source of innovation. All players contribute to the health of the ecosystem – that is, whether it is successfully creating continuous and step change improvements in outcomes for individual members and for society as a whole. Innovation ecosystems create mutual benefits; they are not zero sum. The health of this system is important for the whole industry, and consequently, of individual companies. VCI asked respondents to describe their views on different aspects of how it works and on what steps could be taken to move it to a level enjoyed by those with benchmark ecosystems – such as the car and aeronautical industries of Germany and America respectively.

Respondents almost universally agreed that the innovation ecosystem in the mining industry could be improved substantially. Despite there being a general commitment to innovation in technology and services on an individual level, companies cited the lack of a common framework to guide industry development as a major impediment. Respondents overwhelmingly identified the development of a common industry technology vision, ‘the need for a coalition’, that allows all in the ecosystem to plan development accordingly. For instance, how can the vision for low-impact mining and fully autonomous value-chains unfold? This is particularly important given the long investment timeframes in mining.

A successful example of this is the highly competitive telecommunications and semiconductor industries who also come together to define industry roadmaps, a necessity given the integration and planning required. Following the recent downturn in the mining industry, technology research and development (R&D) tends to be focused on more immediate shorter-term concerns. Many larger companies place a big emphasis on using universities for their frontline research, particularly in Europe, America and East Asia. A successful mining industry innovation ecosystem requires the different roles playing their part, combining to create the incentives to partner long term.

Shaping the Industry Innovation System

<table>
<thead>
<tr>
<th>Company type</th>
<th>Value proposition in innovation ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1 mining companies</td>
<td>Use long-term innovation to efficiently extract value through platform change</td>
</tr>
<tr>
<td>Large service companies</td>
<td>Develop in-house technology and act as integrator for smaller providers</td>
</tr>
<tr>
<td>Tier 2/3 mining companies</td>
<td>Select the few technologies that will make marginal assets profitable</td>
</tr>
<tr>
<td>Small service companies</td>
<td>Develop niche technologies and sell them to mining and services companies for value add</td>
</tr>
</tbody>
</table>
PARALLEL INDUSTRY ECOSYSTEM EXEMPLARS

Common attributes: long-term vision, long-term partnerships, leadership by biggest companies, high investment in research, links with universities and research bodies, innovation openness and aggressive competition between companies.

1. Semiconductor industry.

The International Technology Roadmap for Semiconductors (ITRS) is a document developed by global industry semiconductor experts. The ITRS seeks to identify future technical obstacles and shortfalls so that the industry and research community can collaborate effectively to overcome these obstacles and build the next generation of semiconductors.

2. German automotive industry.

Regionally close. Long-term working relationships. Recognised symbiotic relationship between suppliers and car makers.

3. Telecommunications industry.

Collaboration on timing and development of big platform changes. Focused on areas of competition (consumer market), collaborate on other areas (infrastructure support). Government alignment with regulation.

EXHIBIT A

Who is impacting the mining industry the most?

“Collaborative and cooperative environments with aligned incentives is the only way to integrate technology innovation growth”
The mining industry, like many others, has several dominant companies that have significant strategic, financial and political influence they can exert upon both suppliers and governments. But these are not the only important players in how the industry evolves. Small and mid-tier miners, large and small suppliers, technology providers, universities and governments all play important roles in the healthy functioning of innovation in mining. Through the initial survey and subsequent interviews, VCI has attempted to understand how each group is performing its role.

Large mining companies typically characterise themselves as fast or conservative followers to avoid the risk of untested technology disrupting large, continuous production systems. This risk is considered too high when added to the long-term market risk that high capital investments already carry. Large miners are often subsequently forced to choose from the technology presented to them without committing to a broader vision to guide supplier technology development. One supplier suggests that it is difficult to make significant investment in step change technology without the large miners individually or collectively committing to a long-term vision for the industry. As a result, competition is largely based on cost rather than product innovation.

An important role of big service companies is to act as technology integrators and to be a conduit for cutting edge technology suppliers into the miners. Feedback from both service and mining companies suggests this integration is not working as effectively as it could. Part of the issue could be a structural gap in the services sector that will be resolved naturally through competition. Another potential issue may be the approach taken towards customer relationships. Respondents articulated that they find it difficult to focus on value due to the emphasis on costs by procurement. In both instances, innovation is often perceived as disruptive, unpredictable and therefore largely suppressed.

EXHIBIT B
Which phrase best represents your company’s approach to technology-based innovation?

An important role of big service companies is to act as technology integrators and to be a conduit for cutting edge technology suppliers into the miners. Feedback from both service and mining companies suggests this integration is not working as effectively as it could. Part of the issue could be a structural gap in the services sector that will be resolved naturally through competition. Another potential issue may be the approach taken towards customer relationships. Respondents articulated that they find it difficult to focus on value due to the emphasis on costs by procurement. In both instances, innovation is often perceived as disruptive, unpredictable and therefore largely suppressed.
Many small technology suppliers emerge from university research as start-ups, working at an opportunistic level to bring new things to market. However, they often lack a clear view of what detailed technology is required through a lack of transparency of the majors’ systems. As a result, they often don’t have the backing to move creative ideas ahead.

This lack of needs-based visibility and funding is slowing the flow of research based innovation into the mining industry.

Publicly backed institutions such as universities, defence and research bodies have always played a critical role in economy-wide innovation. The mining industry is no exception. However, currently this role in the mining industry appears to be diminished. Traditional mining schools are less central than historically and the biggest and most innovative global research institutions are not as involved in mining as they could be. Furthermore, universities that are actively involved tend to look to government for funding more than to the industry. Many mining executives (37%) believe that an answer to improved innovation in mining lies in building better ties between businesses and universities, improving transparency, communication and objectives.

“We are a small company struggling to develop a couple of small projects and do not spend any time thinking about innovation or how to develop it. So I stopped answering after a bit. Sorry.”

Most questions in the State Of Play survey required respondents select 3 choices from a long list. The figures quoted in the text refer to the percentage of respondents who chose an individual choice. The figures refer to the total proportion of selections for an individual choice (and so add to 100%). As such, the percentages quoted in the text may differ from those on the graphs.
Governments have the potential to play a vital role in shaping the future, but have work to do. They have the capacity to influence the evolution of global mining technology hubs and how they interrelate. This is a point underlined by respondents, around half of whom (44%) chose the development of ‘incentives to attract technology based service companies’ when asked what government can do to encourage innovation in the industry. In such a global industry, ultimately the answers will have to come - as one respondent says - ‘from the mining industry itself, not from the government’.

“Equipment suppliers often have a commercial driver to lead the innovation effort. Large mining companies have the greatest capacity to fund R&D efforts, but the company’s commitment to any R&D program can wax and wane with management changes. Really complex innovation, such as major process technology shifts, still often requires input from ‘expert’ research institutions.”

EXHIBIT C
Which overarching government or industry body action will have the biggest impact on innovation in mining?
Partnerships, Collaboration and Innovation Flow

Partnerships and collaboration creates the necessary flow for the innovation ecosystem, but feedback from mining executives suggests that the industry needs to be more deliberate in forming and maintaining substantial strategic partnerships. The result is demonstrated by respondents saying a transactional attitude towards suppliers is the biggest problem facing collaboration in mining. Toyota is a famous example of how a business benefits from working with suppliers better. Toyota actively invests in educating and training their suppliers and helping them scale their business. The result is that their suppliers are more innovative and creative. Toyota realised quickly that a large degree of their own innovation was reliant on – and driven by – their suppliers.

Without the development of targeted strategic partnerships, collaboration with key suppliers can falter due to poorly aligned objectives resulting in complaints of a poor fit from both sides. Interestingly, it seems that effective supplier relationships tend to go hand-in-hand with active leadership in the industry. Two-thirds of companies that ‘lead across industries’ have supportive relationships with their suppliers as opposed to only half of self-described ‘conservative followers’. The key skill is in identifying which relationships should be targeted as strategic partnerships and which partnerships should be predominantly cost-based. These will likely be in those areas with little potential innovation and which are commoditised.

EXHIBIT D

Which phrase best represents your company’s approach to technology based innovation? In your stated key focus area, how are suppliers helping you to achieve your goals?

One of the main challenges facing miners when considering collaboration with suppliers is the prospect of intellectual property leakage and securing proprietary knowledge (given each large supplier generally works with each large miner in some capacity). In most instances there is no real competitive advantage to defend, and in these areas using open collaborative approaches are no threat. As in all corporate strategies, clarity in defining where you will compete and win is critical. Although industry structure and gaming considerations are always central concerns, other industries have shown that it is not the technology you use that differentiates performance, but ‘how it is stitched together that adds the most value’.

Other, more overtly intellectual property-conscious industries are moving away from protecting intellectual property. Elon Musk, for instance, has declared that he will not defend patent infringements for his electric car company, Tesla. The reason for this is the lag effect. By the time other companies have interpreted, developed and commercialised Tesla’s intellectual property, Musk would expect that Tesla has already moved on. It is worth protecting if it can provide a competitive advantage or keep competitors at a higher cost base, but not at the cost of having sub-optimal technology. So, does intellectual property matter as much anymore? Companies need to individually decide on this point. Whatever the choice, close consideration of the impact of a particular stance on innovation with partners is important.
What are the main impediments to productive innovation partnerships between miners and suppliers?

Business model innovation is beginning to change the landscape with respect to supplier relationships. Suppliers are moving away from the traditional approach of selling their products outright with separate service contracts. Increasingly, suppliers are providing a single long-term service contract that includes access to equipment, maintenance and operational support, where both performance and costs are agreed in advance. Data and analytics is also likely to have increasing impacts on the speed and nature of business model innovation. This evolution may also help overcome the cost-focused role played by procurement.

“Autonomous innovation is being driven by the coming together of three groups (miners, suppliers and universities)”

Several large miners and service companies are currently taking the lead in specific areas of the value chain, such as remote mining and deep mining. Despite this, the industry is still restricted by an innovation ecosystem which is not functioning effectively and without an adequate current push to shape it beyond some efforts to drive common standards. Companies are currently working largely in isolation and the long-term industry thinking and planning necessary to achieve significant improvements is absent. The key question is: how to create a virtuous cycle of innovation between the components of the ecosystem? If mining companies are not seeing the value of innovation and demanding it, then suppliers won’t provide it given it is more costly to develop new innovations than it is to sell the same products.
Ecosystem: Recommendations

1. Industry coalition roadmap

Build a coalition that shapes the industry development roadmap for step change. This is crucial to address the timeframes involved, to support platform integration efforts and to provide the clarity of direction required for service companies. It can be catalysed by the influential few to create critical mass and structurally define needs, standards and direction. Government has a role in facilitating information exchange between companies, and in creating incentives, but essentially this is an industry leadership task.

2. Improve business and university working relationships

Improve the innovation flow from research to innovation to commercialisation. Businesses should see universities as a source of innovation, not just a set-and-forget philanthropic financial contribution, and move the interaction to more of a commercial proposition. Government has a major role in reforming university research to help it become more accessible for businesses, and to incentivise researchers to seek out industry interaction.

3. Improve system for funding flows

Increase the flow of funding to innovation in the industry. Educate shareholders on ways of valuing companies and on financial metrics that take account of longer term views and strategies. Establish mechanisms that can be used to get more funding into step change innovations, including from venture capital which has a relatively low exposure to the industry.

4. Build role of industry integrators

Encourage and establish key industry integrators, both as companies and as integrating systems, standards and protocols. Large service firms can partially play this role, providing access to large miners for small service and technology providers. There is a compelling opportunity for service companies to focus on this as a business model – sourcing, adapting and scaling innovations, and assisting mining companies to adopt them.

5. Establish forums for needs exchange

Establish forums in which key industry players can interact on vital needs. Needs analysis, coupled with collaboration, is a basic element of innovation. Contributors would include large and small miners, large and small service companies, technology providers, research institutions, universities and governments. Design framework and model for engagement.
Chapter 2: STRATEGY

How do companies define their innovation strategy in relation to their corporate strategy? How are these related to prevailing global and industry trends? How do they communicate this with their business? How successful are they? These are a selection of the questions this section attempts to answer. Our recommendations are pitched at the executive leadership of mining and service companies.
CHAPTER 2: Strategy

Strategy development starts with understanding the big trends in the external environment and then positioning to create opportunity and mitigate risk in response to this knowledge. The mining industry is well aligned on what the major trends facing the industry are. For the second year running, technological change is rated as the most important trend over the next 15 years, chosen by 52% of respondents. Many experts agree that we are entering an incipient point in the use of technology in business. The combination of communication advances, robotics and automation is expected to create transformational change in the coming decades.

Closely related, is the entrance of a new generation of technically aware people into the mining industry, which was chosen by over one third of respondents as being a highly impactful driver of innovation in future. This is a generation who are technologically very competent and who have grown up in a world of consistent change.

“The question that mining companies used to ask was ‘how much per kWh?’ Now we are facing restrictions on the amount of energy available, yet we are still using antiquated equipment like the ball mill that is only 3% efficient. A newer generation of people entering the industry will bring new skills.”

The potential impacts for implementation of new data-centric operating models and change programs are significant. In parallel, the workforce is ageing as people stay in work longer, often in a part-time capacity.

EXHIBIT F

Which of the following macro trends will have the biggest impact on innovation in mining over the next 15 years?

- Technological change and disruption: 120
- Increasing environmental pressures: 59
- Technically aware generation entering the workforce: 77
- Rising importance of the developing world: 72
- Energy production technology shifts: 66
- Global regulation and transparency: 46
- Ageing workforce: 32
- Global skills pool growth: 26
- Geopolitical tensions: 25

Count
Environmental pressure is the second-highest rated concern of mining executives, with 43% of all respondents believing it will be a major driver of innovation. Requirements for social licence to operate (25%) and increased mining in difficult places (29%) also rated highly. In an apparent disconnect, social, economic and environmental development was rated second-last as a value chain focus area for innovation. We had a similar result last year and so we asked respondents why this was the case. Over two-thirds of respondents suggested operations take priority and many more that it is non-core. In a period when a failure in this area has caused the industry to realise long-standing sovereign risk fears, such as the large-scale strikes in South America and South Africa, imposition of resource taxes in countries such as Australia, threats of nationalism (particularly in Africa) and difficulties securing staged approvals (such as in Mongolia), it poses the question: should social, economic and environmental development take a higher priority within the mining industry?

“In my view, climate change is the single biggest issue facing large operations in the next few decades. It drives the need to reduce overall energy and to find cleaner energy options (and it may well increase the price of “green” existing options such as gas, etc.”

EXHIBIT G

Responses from last year’s survey indicated that innovation in social, economic, environmental and community development was a relatively low priority. Why do you think this is?

Most questions in the State Of Play survey required respondents select 3 choices from a long list. The figures quoted in the text refer to the percentage of respondents who chose an individual choice. The figures refer to the total proportion of selections for an individual choice (and so add to 100%). As such, the percentages quoted in the text may differ from those on the graphs.
All countries tend to become more concerned about the environment as they mature into developed economies. Previously considered to be relatively unconcerned about environmental pressures, China is now the world’s largest investor in renewable energy while actively forcing the closure of high emissions businesses and piloting emissions trading schemes. In the developed world, investment funds are being used as an instrument to apply pressure on behalf of ethical investors.

At an industry level, the biggest concern is with declining ore body grades. Given that the competitiveness of mining companies is largely determined by the quality of their ore body and how it is ‘husbanded’, this may not be a surprise. In reality though, average grades are not so important. What matters is the relative decline of company grades with one another, which is why it is initially surprising that explorers are not ranked highly in the survey in their impact on innovation. Several respondents, however, note this reflects slowing industry growth and predict it will increase in the future.

Strategy Direction and Articulation

Strategy processes typically identify asset portfolios and set development and output targets for assets.

Yet when it comes to articulating the competitive advantage that will allow assets to be acquired, developed and operated at a higher return than others in the industry, there is often little detail. The tendency in many mining companies is to emphasise planning work at the expense of core competitive strategy work.

Creating and maintaining competitive advantage by definition requires innovation. When faced with 20+ year asset investment decisions, embedding such concepts becomes even more important, and perversely, also less likely to be achieved. Long asset life and price cycles can lead to fundamental core competencies not retaining sufficient focus – particularly the commercial acumen required in navigating cycles and long-term industry trends.

“Innovation is not considered to be a non-negotiable for success, but following correct processes and procedures is. We are innovative in response to challenges, but not proactively. In high margin operations, we can still look successful without the stress of having to be proactively innovative.”
Large asset decisions such as greenfield development and major brownfield expansions are decisions that carry risk and there is little companies can do to avoid this if they are to maintain sizeable equity positions. Over time this has created what many respondents described as a conservative culture with respect to taking risk in development design or operating approaches and technology. This is particularly the case when associated with core process. Companies therefore tend to focus on lower-risk innovation in their value chain, driven by perceived necessity and short-term market metrics. The consequence is that the core process in mining is often much like it was 30 years ago – except that everything is bigger. Service companies have not significantly changed this, opting to develop products that fit into existing mining systems and struggling to articulate or sell large-scale platform changes.

Executives agree that greater alignment on vision is required between suppliers and asset owners both for platform change within the industry and for specific assets within their businesses. A key component, which is common in the car industry, is the cultivation of strategic partnerships. A network of strategic partnerships around large mining companies would enable risk-sharing and value-based relationships with a shared focus on long-term outcomes. These relationships should be defined at a senior level and managed in the context of developing and maximising the value of the asset. In many instances, relationships which should be strategic are managed transactionally on the basis of cost by procurement officers, putting optimal development pathways at risk.

The differences between the approaches of large and small mining companies are stark. Small mining companies are far more likely to say their innovation program is failing to meet expectations. Their model, which is very consistent, is to use an unstructured, ad hoc innovation approach and rely upon existing hierarchies to implement already proven technology. In contrast, large mining companies claim a far higher degree of success using predominantly structured, companywide innovation programs using a wide range of change management approaches. These differences can be attributed to the availability of resources. But they do also illustrate a broader point that technical innovation does not happen without vision, structure and support.
FROM TRADITIONAL TO NEXT GENERATION PARTNERSHIPS

Strategic partnerships should be entered into with a similar mind-set to joint ventures. A framework for partnering for long term innovation success should have:

- A mutual understanding of key stakeholder motivations and culture
- Shared goals and vision for the partnership
- A willingness to actively nurture the (trust-based) relationship over time

The traditional “Push” approach is both wasteful and inefficient.

A better approach is to align the known and unknown needs of the operations with the supplier innovation pipeline.

The diagram illustrates the transition from a push-based relationship to a pull-based relationship, emphasizing collaboration and alignment between stakeholders.
EXHIBIT I

How structured is your approach to implementing new innovations in your company?

How successful have introductions of new technology been into your business?

Innovation Focus

Executives are in broad agreement on the areas of focus for their innovation efforts today and on those likely to impact innovation over the next 15 years. Extraction (chosen by 31% and 34% of mining and services respondents respectively), processing (43% and 30%), energy consumption (21% and 39%) and automation (27% and 46%) are the focus across both miners and suppliers, big and small. The combination of these focal points is not surprising. Mining companies compete on the basis of the total cost of extraction (capital and operating) and these elements go to the core of doing less work for a given product output.

“In the mining industry strategy comes (mostly) from the actual asset endowment and is therefore driven by what is in the ground. Technology strategy and tactics are driven solely by how you extract value from what is in the ground.”

Each of these areas is fundamental to the core process and implementing significant change requires systemic design and long-term planning. The outlier of the highest ranking focus areas is data and analytics, chosen by a surprisingly low number of mining companies relative to service companies, at 5% and 15% respectively. Many across the industry expect this to be a strong focus in the future, reflecting the increasing focus on data-led operations and optimisation.

Some individual, leading mining companies rated data and analytics very highly and, as a whole, the industry is predicting its importance will increase over the next 15 years. This suggests that mining companies could continue to look more closely at how innovation in data use could improve their profitability.

“Data is the last untapped orebody to exploit”
WILL ENERGY BE THE NEXT DRIVER OF GLOBAL TRANSFORMATION IN THE MINING INDUSTRY?

Energy cost is predicted to be the 2nd most important driver of innovation over the next 15 years. Focusing on energy reduction as a goal will force companies to take a systemic approach to innovation. New metrics are possible to focus innovation – for instance, energy use per tonne of product – as opposed to the traditional, and often ineffective, measure of people per tonne per product.

There are two major parallel streams of innovation to consider:

1. **Use less energy by moving less rock and doing less work.**

If mining operations are mostly about breaking and moving earth, both of which are energy intense, doing less of each will be a big driver of energy reduction. Importantly, work reduction targets and a low footprint can act as both a powerful cultural driver and as a catalyst for innovation. Reducing energy will also have safety benefits. Focus areas will potentially be in areas such as automation, extraction or comminution and processing.

2. **New power generation, storage and conservation technologies.**

Technologies such as solar are already cost-competitive with existing diesel power sources on most mines and battery storage is improving rapidly. Monitoring and energy recycling technologies are advancing rapidly. The biggest challenge with new sources and technologies is integration with existing operational systems.

Energy cost is predicted to be the most important driver of innovation over the next 15 years. Focusing on energy reduction as a goal will force companies to take a systemic approach to innovation. New metrics are possible to focus innovation – for instance, energy use per tonne of product – as opposed to the traditional, and often ineffective, measure of people per tonne per product.

INNOVATION AND SAFETY

Respondents to this year’s survey indicated the mining industry is placing a relatively low priority on the direct application of innovation to improve safety outcomes. Safety is undeniably a top priority for mining companies with substantial resources invested in improving outcomes. Why is there an apparent disconnect?

- **The safety challenge is seen as more of a behavioural issue than a technological one.** Many common industry safety approaches are based on models of behavioural progression. Improvement in behavioural training and approaches are likely not to be immediately recognised as innovation, despite this being a considerable focus of research and development.

- **The technical focus areas selected by respondents will likely have significant safety benefits.** Automation, robotics and low-impact extraction techniques all involve less work, less energy and less interaction between workers and equipment.

The industry is innovating in safety and can look forward to further improvements in the future.
What is striking about the State Of Play data is the contrast between the stated importance of technology shifts for mining companies and the general reluctance to lead. Risk is undoubtedly a factor, but perhaps it is also partly due to the difficulty in translating a strategic insight into an effective response. This is especially the case when it involves a decisive movement away from the established status quo, which is a challenge faced by all businesses regardless of industry.

Strategy Development and Communication

When asked what their company could do to best improve innovation, the top answer for the past two years was to link innovation to corporate strategy. Of particular interest this year was the question of why there is a disconnect between strategy and innovation. The two highest responses were simply that there is no dedicated innovation strategy, and by inference, likely no technology strategy (chosen by 33% of respondents). In addition, respondents added that the corporate strategy does not define competitive advantage (20%). The industry overwhelmingly sees innovation as highly important to the success of their corporate strategies, so why the difficulty in aligning the two? Not adequately defining competitive advantage is certainly one reason. Another potential reason, as highlighted in the interviews and data, is the highly variable involvement of the chief strategy officer in innovation, a good indicator of this disconnect.

Increasingly, best practice strategy is very open, objective and communicable. Openness to the outside and objectivity are fundamental to seeing the opportunities and threats that will drive the awareness for innovation. This is all the more powerful when taken in combination with possibly one of the most effective, simple and overlooked solutions to improving innovation outcomes: communicating the strategy to the broader business. If executives can successfully ensure those below the strategy makers understand what the corporate and innovation priorities are, they can efficiently target their efforts and investment priorities at the appropriate level of risk.

Almost one quarter of respondents said they have no dedicated innovation strategy and half said their innovation processes are ad hoc or unstructured. This implies that innovation is undervalued and under-resourced in many companies, particularly mining companies. It also suggests that innovation is positioned at too low a level in organisations to fully architect the top-down and bottom-up approaches necessary. A reason for this appears to be the leadership gap in who is driving innovation. Chief strategy officers are rarely seen as a driver of innovation strategy in mining companies. Unusually, the role of chief strategy officer of mining companies is often combined with the chief financial officer. Consequently, they are known for being heavily governance-oriented and less driven by innovation outcomes. For many companies, this is supported by the fact that innovation and strategy are unaligned.
EXHIBIT K

Responses from last year's survey indicated that there is a disconnect between innovation and corporate strategy. Why do you think this is?
1. Develop and link business strategy and innovation strategy

Establish a framework by which corporate strategy directly drives innovation strategy. Objectivity in defining competitive advantage and the innovation that is essential will drive clarity in the innovation program. Look at your long-term drivers and ensure there is a link to innovation strategy. Mining innovations are characterised by the long timeframes that need to be considered and planned for. Within these timeframes the world can and does change dramatically and as such, innovation strategy should look beyond the current suite of technology.

2. Clarify intellectual property stance

Consciously design intellectual property stance to balance competitive imperatives with need for absolute improvement. Target defence of intellectual property towards those areas where the company has, or is looking to achieve, competitive advantage. In other areas, actively accumulating and protecting intellectual property is unlikely to be productive. Categorise and approach relationships with suppliers in alignment with intellectual property needs.

3. Ensure innovation is not just top-down or bottom-up, but both

The random generation of ideas that innovation requires is unproductive unless undertaken within a clear structure and with clear direction. Leadership should set the tone, goals and priorities for innovation that will guide innovation efforts and resources all the way through operations. Enabling freedom to create and test ideas is important in allowing the serendipitous innovation that cannot be solely directed top-down.

4. Be deliberate on strategic partnerships

Be clear on where your company will have open partnerships and where it will not. Be clear on which relationships are strategic and which ones are cost focused. With all other partnerships and suppliers, work with them to develop a pathway towards being a strategic partner with aligned innovation programs. Focus on timeframe, challenges and mutual benefits. If you are going to partner, partner early.

5. Communicate, communicate, communicate

All the best strategy in the world is redundant if no one knows or understands it. Crystalise innovation strategy into easily communicable and relatable pieces – much as several Tier 1 miners have successfully done with their corporate strategies. We have heard a lot about shortage of capability, but it is often the companies with the least resources that out-innovate those with capacity – this is because they set direction, expect change and communicate.
Chapter 3: DELIVERY

Focused on how companies develop and deliver innovation, looking at the success of different structural options, leadership and culture, partnerships and the best approaches to change. Recommendations are aimed at improving outcomes within the mining value chain, including the role suppliers play.
Fittingly for such a large, geographically and culturally diverse industry, respondents displayed a wide range of structural innovation approaches. Analysis of the responses from mining executives has provided a clear picture of which approaches, or combination of approaches, tend to be the most successful and which are not.

There are two types of companies who have an active and well-resourced innovation program:

1. Mining or service companies whose innovation focus is long term and requires high capital expenditure (e.g. large asset transformations or major new capital equipment development)
2. Service companies whose innovation focus is short term with lower capital investments (e.g. fast product cycles or incremental improvements)

Generally, the companies who felt they had a successful innovation program were biased towards section A or C in the matrix below. However, the best companies will have a combination of both top-down and bottom-up delivery. Mining companies who said they had a relatively unsuccessful innovation program tended to fall into category B or D. Due to the fundamental importance of this, we sought out the chief technology officers of several of the most innovative mining and services companies to understand their approach. These insights are interspersed throughout this chapter.

Each company interviewed indicated that the only way to make successful long-term operating platform change is through a strong top-down approach, guided by a clear vision and systemic roadmap of development projects. Short-term focused innovation – for instance, some services and incremental operations improvements – is usually better performed by those doing these tasks on a day to day basis or specific teams working with a fail-fast ethos. That is, bottom-up. However, their creativity and ideas will be wasted if not also supported by clear structures, processes and incentives that are communicated well to encourage effort.

This chapter will consider these contrasting approaches and the requirements to deliver them successfully.

![Diagram showing top-down and bottom-up innovation approaches](image-url)

- **Top down, strategy driven innovation**: If primary focus, this can be too slow, not sufficiently innovative and can lead to initiatives which do not respond to emerging challenges.
- **Shorter time frame, lower capital**: Operations and customer focused. Based on processes and incentives to build necessary culture across business and manage resulting ideas portfolio.
- **Bottom up innovation**: Projects to address emerging issues, however, can lead to ad hoc initiatives which fall because they are non-systematic.
- **Top down innovation**: Technology and strategy focused. Based on stretch vision and systematic design with structure to manage integrated innovation processes and phased implementation.
- **Longer time frame, larger capital**:
Innovation Philosophy: Top-down & Bottom-up

Most large mining companies use top-down delivery and many smaller mining companies tend to use bottom-up delivery. There is good reason for this. Smaller mining companies often simply do not have the financial or managerial capacity to dedicate to long-term innovation programs and so default to an unstructured, ad hoc approach. The best and most successful innovation tends to happen when individuals are incentivised to innovate within a well-designed, supported system of innovation tied into a companywide vision. Creative innovation needs structure and clear processes, but this doesn’t have to be expensive.

EXHIBIT L
How could you best improve innovation in your company?

A critical step in enabling innovation is the articulation of a long-term vision, grounded in strategic logic, to guide change. The success of this approach is evident in Rio Tinto’s Mine of the Future™, which has achieved an operating model paradigm shift within bulks, and AngloGold Ashanti’s deep mining innovation consortium in precious metals. Both illustrate that clear progress is possible, with manageable risk, when built upon a clearly defined set of challenges within a systemic roadmap. This framework enables ‘emergent strategy’ where top-down focus enables widespread creative contribution.

Companies who implement technology and innovations within a whole of company view of the ‘to-be’ state overwhelmingly rated their innovation programs as more successful. It is also the only way to facilitate step change development, using roadmaps and managing innovation challenges as a portfolio.

A systemic transformation program for vision-led change requires clear executive ownership and strong communication within the business. An important caveat to this statement is that it needs to be the right kind of leadership; over-controlling and prescriptive leadership can smother an innovation program. Some degree of independence is necessary.
HOW TO IMPLEMENT A ‘VISION-LED TRANSFORMATION’

Step change transformation can’t come from incremental ad hoc improvements to the current system. If step change is the intent, then a vision-led approach is the best method:

1. Define the overarching vision for step change by taking both a top-down and bottom-up approach
   - Top-down – Define risks and opportunities that address key strategic challenges and external forces impacting the business
   - Bottom-up – Identify issues in the current system and operations to identify target areas for innovation, ensuring operations and the business are included

2. Articulate the development roadmap to achieve the vision. Outline major challenges and translate into targeted projects to manage and progress the transformation

3. Use a range of innovation methods – select the innovation method best suited to the specific challenge

This will maximise the development’s chance of success from both a technical and change management perspective.
1. Innovate to improve the current operations: Issues identified for improvement in the current operations (current model)

2. Innovate to improve the next generation operations: Greenfield design, ability to address systemic challenges (next model)

3. Innovate for the future mine: A guiding vision for future clean sheet design incorporating external technology shifts and future trends (concept car)

Designing and implementing an effective innovation architecture is key to long term productivity improvement. VCI’s model for innovation architecture is derived from the car industry and is based on three levels:

Using this approach helps to focus at each level as they all require different skills and have distinctly different cultures. Challenges that are identified at each level push into the next as innovation challenges, while implementable breakthroughs at the higher levels cascade down for implementation in levels below.
EXHIBIT M

How successful have introductions of new technology been into your business? How structured is your approach to implementing new innovations in your company?

Leadership and Culture

A principle of innovation theory is that the most consistent and successful innovation programs are driven by a proactive and visible leadership. This is underlined by the companies who rate their innovation programs as highly successful and who also rate their CEO as the primary driving force behind innovation.

EXHIBIT N

Who are the biggest driving forces for innovation in your company? How successful have introductions of new technology been into your business?
Visible leadership and clear processes support an innovative culture, but if the emphasis is on hierarchy and micro-management, the outcome may be unproductive. Thus, getting the balance right is important. Leadership and culture were also rated the best risk management tool by self-described innovation industry leaders.

Generally, the data indicates that public recognition is a preferred form of incentive to drive innovation compared to specific targets and bonuses. But it does pose a larger question: how are people really rewarded? Is it how leaders intend? Given 40% of CEOs say their company has an innovative culture while only 8% of COOs do, what leaders think and what is actually the case may sometimes differ. A huge number of respondents said that their companies do not reward innovation at all.

Technology Development Methodologies and Partnerships

The mining industry has a range of innovation methodology and partnership options available to it, but it tends to choose only a few. Miners frequently demonstrate a preference for in-house – or closed – innovation matched with a relatively transactional approach to partnerships. Service companies show a preference for in-house R&D but are increasingly pushing for a more integrated design approach with mining companies.

There is space for a more nuanced approach. Currently in the mining industry, it seems innovation is being stifled to some extent by large companies marginalising smaller service companies. This is justified by miners on the basis that small companies lack the required scale to roll out products throughout the larger mining companies, who are in turn more likely to use off-the-shelf technology. Generally, mining companies with a supportive culture for innovation are more likely to use a broader range of development methods other than buying off the shelf from suppliers.

**EXHIBIT O**

How does your company primarily develop required technology?
The box below shows the different innovation methods available for different innovation challenges, ranging from low complexity process-based challenges to long-term challenges within a value chain. Choosing the right approach for specific challenges and tasks is necessary. Selecting the level of openness of the innovation approach is a capability that requires deliberate assessment of the challenge faced – for both miners and service companies. Considerations include complexity of the challenge, level of innovation required and timeliness.

DIFFERENT INNOVATION METHODOLOGIES FOR DIFFERENT CHALLENGES

Approaches that look outside the industry, such as open innovation and closed consortia, are considered less popular within mining than more inward options. The data suggests open innovation is viewed with uncertainty by many large companies despite being increasingly used by leading companies in parallel industries, such as Statoil and General Electric. Possible reasons for this are a perceived lack of value, culture, intellectual property and a lack of understanding of how, where and when to use open innovation.

Targeted open innovation strategies have already been proven successfully in the mining industry. For example, running supplier forums to share areas of development, using open innovation intermediaries or technology scanning for specific requirements.
WHY AND HOW TO USE OPEN INNOVATION

Open innovation is about building a system where ideas flow openly from customers, employees and suppliers. This allows ideas to be captured and developed collaboratively, leading to sustained innovation.

The benefits of open innovation are compelling:

- **Draws the outside in** – Access to the external world and other industries to solve challenges
- **Enhances brand position** – Engages with the new technically-aware workforce and external community
- **Shifts culture** - Acts as a demonstration of the new future of openness to innovation within the business
- **Clarifies key challenges** – It is a no-regrets first step, and others can often see challenges you don’t

Even if you don’t have a full, top-down open innovation program, the first steps towards openness are not a big a jump.

- **Communicate your challenges to suppliers** – Hold forums inviting suppliers to innovate on specific challenges
- **Run innovation workshops** with groups of suppliers on a specific challenge
- **Run a test case** - Hold an open competition on key challenges to stimulate a broader open innovation process

USING INNOVATION FOR SOCIAL, ECONOMIC AND ENVIRONMENTAL DEVELOPMENT (SEED) CHALLENGES

SEED issues are some of the highest value challenges to solve and also some of the toughest.

Innovation can be used for SEED challenges in a manner similar to the way it is used for many difficult issues. It can help to identify poorly understood needs within the community and enable an inclusive process that achieves ongoing structural improvements.

Our suggested approach for applying innovation to these challenges includes:

1. **Discovery** - Using ethnographic and observation-based approaches to understand the real needs of the community (not necessarily those with the most publicity)
2. **Collaborative ideation** - Holding open ideation workshops with the community to find mutually beneficial solutions to identified challenges
3. **Prototyping** - Testing and fast failing solution prototypes in the community to understand quickly whether something will work, what the potential issues may be and to build momentum

Venture capital is surprisingly unpopular given the funds available globally and the highly prospective nature of many new mining technology companies. It is routine for larger service companies to acquire smaller technology businesses as a source of innovation, effectively outsourcing the risk to the start-up technology sector. The venture capital investment style of mining companies is predominantly to ‘farm into’ discoveries by small exploration companies.
Implementing Technology and Change

The success of a new product or service in the mining industry is measured by whether it improves performance in the mining value chain. Very often the failure of a new innovation isn’t a result of poor technology – change management and human factors are a large determinant of success. Even the best innovations can be derailed by lacking a high-level systems view when addressing root causes, or poor communication.

The most successful companies at implementing technology take a deliberate approach to change management, placing external or internal specialists in charge of the process and fostering good communication. Few companies like using change management teams and high-end specialist teams are most popular in some industry sectors, while cross-functional taskforces are popular everywhere. A common theme throughout the industry is that poorly executed change management is bad, but when combined with a large amount of change, it can be disastrous. The innovation implementation team will likely be more successful if devoted solely to innovation projects. The team should also have a good understanding of the technical aspects of change as well.

EXHIBIT P
Responses from last year indicated that innovation implementation success rates across the industry are quite low. Why do you think this is?

![Bar Chart](image-url)
1. Establish vision-led roadmaps

Establish innovation and technology development roadmaps to drive major investment decisions and ensure that they have an ongoing budget, clear timeframes and technology focus areas. A long-term asset (green-fields or new brownfields expansion) needs step change planning.

2. Use systemic design for risk management

Risk reduction will not be achieved by being a fast or conservative follower, but by knowing when leadership is necessary, being systemic in designing the business operating platform and by managing phased change to it. In particular, risk reduction will be achieved through understanding how a potential change fits with, and impacts, the overall system.

3. Use a range of innovation methodologies

Understand and use the breadth of innovation methodologies available (include scanning and venture capital). Be deliberate in choosing the method required for a given challenge and concentrate on bringing the ‘outside in’. Include suppliers in the innovation process. To ensure integration, manage the differing innovation approaches to technology challenges at a program level.

4. Apply visible leadership

Deliberate leadership is critically important for both top down and bottom up innovation. Top down goals and design criteria need to be set whilst simultaneously cultivating a bottom up innovation culture. Clarity in top down expectations enables step change, while empowering bottom contribution will help change management. Provide a structure for unplanned innovation, because it needs a specific strategy and design. Protect and incentive change, punish inactivity not mistakes.

5. Team structure for change implementation

Establish a clear change management methodology for technological implementation that provides specialist input, clear processes, communication pathways and structure. Involve change management teams throughout the technology development process in order to ensure consideration is given to strategic fit and operational interruptions.
The mining industry is under severe pressure following the commodity price boom. Unless companies apply innovative processes to their strategy, architecture, business improvement and management practices, some may not survive. Innovation is not discretionary in any business that is seeking sustained success. This statement is reasoned from the simple logic that superior returns by definition demand competitive advantage, and competitive advantage is founded and sustained by ongoing innovation. Therefore, strategy and innovation are in many ways synonymous and it is not possible to examine one without considering the other.

It was not surprising then that when asked ‘what could be done to improve innovation effectiveness within your company’, the most prominent response was to strengthen the link with strategy. Through the analysis it became apparent that this link was highly variable across the industry, but in companies where clarity existed, innovation programs were deliberate and largely successful. The analysis also demonstrated clearly that successful innovation processes to adapt strategy, architecture and management systems must be driven by the CEO and strategists and defended against a reversion to formulaic, planning-based strategy processes.

Impactful innovation in mining companies is dependent upon a creative and healthy ecosystem of players across the research, services and funding sectors. This ecosystem is currently immature; relationships are considered transactional, ideas exchange is stilted, integration is lacking and venture funding is insufficient. Rectifying this situation requires leadership from the industry’s most influential companies to shape industry policy, structures and norms. Success will ultimately be measured by the flow of new value-adding ideas, products and services offered by suppliers that change the industry.

Participating in the innovation ecosystem is not a zero sum competitive game. All parties stand to gain from improved products and operations, especially those close to their suppliers. Many of the world’s most innovative industries, such as semiconductors, telecommunications and car manufacturing, recognise this and actively invest in selected long-term, strategic partnerships. Miners and suppliers can be more deliberate in both who they partner with and the cooperative development approach taken within these partnerships.

The current issues with the industry ecosystem, alignment of strategy and adoption of strategic partnerships can be partly attributed to the conservative mind-set in mining towards technology and innovation. This conservatism is understandable since existing risk exposure to the market, ore-body and project delivery is often high. However, the data shows that this conservative approach can be higher risk than a more proactive approach where stretch visions are set and clearly phased innovation roadmaps established. The additional risk of conservatism tends to come from the reduced optionality of locking in old technology to new assets, and through the stunted capability that this mind-set causes, new technology is inevitably more likely to fail when it is introduced.

The structure of innovation programs across the sector for successful companies varied considerably. High capital long-term programs tended to be characterised by a ‘top-down’ direction of programs with delivery through strategic partners and research. Shorter term challenges with less capital impact were characterised by frameworks that encouraged universal ‘bottom-up’ participation. What was common in the successful companies analysed and interviewed was strong visible leadership and the deliberate design of structures and processes that would engender a culture supportive of innovation. All of the successful companies interviewed expressed innovation as being part of their DNA.

Successfully integrating a new product or innovation into an existing system is a case study in doing the simple things well. Construct a well-planned cross-functional change management team, including experienced specialists, and design a change management program with a clear process and open, outward communication. Change management will succeed or fail on the quality of its people and so this should be the focus. While deceptively simple, it is a real challenge to maintain an irregularly used change management capability through the cycles and managing the sometimes uncomfortable relationship that businesses engaged in steady state operations have with project teams.

CONCLUSIONS
ACHIEVING INNOVATION SUCCESS

Taking all this into account, as a CEO there are several things that you can do to drive innovation in your business:

1. Participate in shaping the industry ecosystem

2. Tightly integrate innovation within your business strategy

3. Create and regularly refresh innovation and technology vision and roadmap

4. Target and build long-term strategic development partnerships

5. Build organisational architecture and culture to cultivate bottom-up innovation

6. Visibly lead, incentivise and communicate your innovation program

7. Deploy specialist cross-functional change management teams
VCI surveyed more than 230 mining executives from over 100 companies. We structured the survey around five areas: External environment; Strategy; Technology; Organisation and Implementation. The purpose of these categories was to not only help us provide a snapshot of the key innovation challenges today but also provide a longitudinal perspective on how innovation is changing in the long run.

We used a variety of statistical methods to understand the focus, performance and drivers of innovation in the mining industry. VCI held several follow up interviews with key industry executives in order to gain added perspective on the most interesting questions to arise from the data. We also surveyed a number of specialists from outside the mining industry to understand a different perspective.

All large quotes in the paper are from comments provided by respondents when completing the survey.

Company names and responses have been kept confidential.
**ACKNOWLEDGEMENTS**

Graeme Stanway, Founding Partner VCI, Perth

Paul Mahoney, Senior Consultant VCI, Berlin

David Andrew, Senior Consultant VCI, Melbourne

Corinna Griebel, Consultant VCI, Perth

Daniel Engelke, Consultant VCI, Perth

Fei Lu, Consultant VCI, Perth

**SPONSORS**

Peter Lilly, Director EZONE UWA, The University of Western Australia

Mark Stickells, Deputy Director, Energy and Minerals Institute, The University of Western Australia