Component Automation in the Australian Mining Industry

A Supplementary Report to Rise of the Machines?

June 2014
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Executive Summary

Background

This report is supplementary to a study that was completed for the Resources Industry Training Council (RITC) by Australian Venture Consultants in 2012, titled Rise of the Machines? Adoption of Automation Technology in the Australian Resources Industries and its Implications for Vocational Education and Training and Higher Education.

This earlier study investigated and reported on the level and trajectory of adoption of automation, remote control and systems integration technologies in the various sectors of the Australian resources industry. It also made an assessment as to the current and likely future impact of the adoption of these technologies on the skills, training and higher education needs of the industry.

A key finding of the initial study was that fully or close-to-fully automated resources operation systems are unlikely to become commonplace in the foreseeable future. However, the industry is currently experiencing relatively rapid penetration of sub-fully automated, or what is termed component automation systems, throughout the value-chain.

Component automation refers to automation, remote control and systems integration that occurs at a systems component level rather than across the system as a whole. The most significant outcome of increased adoption of component automation is a proliferation of mostly machine generated data that can be used to optimise operations.

This supplementary study explores in more detail the adoption of component automation in the Australian resources industry, particularly mining, and the implications of this phenomenon on skills requirements, training and education and the skills relationship with some other industry sectors.

Trends in Automation in other Industries

The market for automated industrial systems that are characterised by robotics continues to grow. The global sales of multipurpose industrial robots has grown from approximately 100,000 units in 2004 to 160,000 units in 2012. This trend is expected to continue with sales expected to reach 192,000 units in 2016. However demand for robotics technology is still dominated by industries with very structured processes characterised by large numbers of repetitive tasks, such as the automotive manufacturing and electrical-electronics manufacturing industries, which collectively account for approximately 61 percent of demand for multipurpose industrial robots. Not surprisingly, the main geographical markets for robotics technology are those that have significant automotive and electronics-electrical manufacturing industries.

While the automotive and electronic-electrical manufacturing industries still dominate demand for robotic technologies, the technology is slowly penetrating other sectors with similar characteristics such as industrial and medical laboratory operations.

In industries that have processes that lend themselves to automation, but which are more complex and variable, the apparent trend is that automation and ICT investments are being made in elements of the value chain where the cost-benefit investment case makes sense. That is, where the productivity dividend per dollar of automation investment is greatest. In many cases this involves investment in component automation, whereby ICT enabled...
equipment produces operating data that can be used to optimise the operations of a piece of equipment, a sub-system or through an Enterprise Resource Planning (ERP) system, the overall operation.

**Component Automation in the Australian Resources Industry**

The elements of the productivity dividend that favour component automation over fully or close to fully automated systems in most cases in the Australian resources industry are summarised in the following table.

<table>
<thead>
<tr>
<th>Driver of Favourable Productivity Returns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Capital Outlay</td>
<td>Designing, developing and deploying customised fully-automated mining systems represents a significant capital investment that must be competitive from a return-on-capital perspective. The fact that component automation initiatives typically involve a smaller capital outlay means that the denominator in the return on investment algorithm is typically more favourable for a component automation investment.</td>
</tr>
<tr>
<td>Labour Productivity</td>
<td>In many cases partial automation will result in the equipment being able to be operated by a less skilled operator, thus reducing labour costs and increasing the pool of labour that can be deployed on the operating task.</td>
</tr>
<tr>
<td>Capital Productivity</td>
<td>Significant improvements in overall capital productivity can be accomplished by effecting incremental improvements in capital productivity through different elements of the operating cycle that can be achieved through component automation rather than full automation.</td>
</tr>
<tr>
<td>Occupational Health and Safety</td>
<td>Component automation can be used to remove people from that part of the process that presents an OHS risk anomaly, achieving the same OHS outcome without fully automating a system.</td>
</tr>
<tr>
<td>Operations Optimisation</td>
<td>Component automation mostly involves equipment and systems that take numerous measurements through a range of sensors, are ICT enabled and networked. The data produced by this equipment can be used to optimise the overall operation.</td>
</tr>
<tr>
<td>OEM Productisation</td>
<td>In response to a larger market for component automation than for customised, fully automated mining systems together with a realisation that component automation can be productised much more easily than customised automation system products, OEMs are investing heavily in component automation systems, rendering them more easily accessible for a wider range of operations.</td>
</tr>
</tbody>
</table>

The implementation of component automation systems in the resources industry can also create operational challenges. These include:

- Creation of productivity stovepipes, where the absence of automation in systems downstream from the component that has been automated means that the productivity dividend that is transferred to the bottom-line can be diluted or even lost.
- Because product development pertaining to automation in the resources industry is relatively new, standards for data integration are as yet to emerge. This creates
challenges for integrating data streams from component automation with the operations overall ICT systems and with other component automation that may form part of the mining system.

- If the investment in component automation requires changing equipment, this change will need to be synchronised with the equipment replacement schedule (unless the investment case is adequately compelling to bring forward the replacement investment). While a number of factors determine the equipment replacement schedule, most categories of mining equipment are now generally lasting longer than has historically been the case.
- Whilst the implementation and effective operation of component automation is less disruptive than a full automation program, it will still invariably require some changes in culture, work practices and the required skills base. This is certainly the case within the part of the operation that works with the component automation, but also often includes other parts of the operation that intersect with the component automation.

Opportunities for Automation through the Resources Industry Value Chain

The initial study focused principally on automation in the core resources industry businesses of exploration, extraction, processing and transportation. Part of the remit of this study was to explore the potential application of component automation to processes upstream and downstream of those activities. With the exception of improved data capture and management from upstream and downstream activities that can be used to support decisions pertaining to those activities as well as the core operations, it would seem that there is limited scope for automation in upstream and downstream activities by virtue of:

- The diverse range of environments in which activities upstream and downstream of the core mining and processing activities occur, which leaves limited scope for standardisation of processes; and
- The less frequent operating patterns for equipment used in many of these applications means that the productivity of capital (capital utilisation) case for automation is often significantly diluted.

Types of Component Automation in the Resources Industry

Component automation covers a very wide range of automation, remote control and integrated operations technologies. Broad categories of component automation include:

- Existing types of mining equipment that has been ICT enabled with sensors and the ability to communicate with various systems that comprise the mining operation;
- Existing types of mining equipment that have been partially automated through technologies such as remote control;
- Equipment and processes that use various sources of internal and external data, often in conjunction with human judgement to optimise their operation;
- New types of equipment that have been developed and deployed specifically for the purpose of creating richer data sets to inform operational decisions; and
- New types of equipment that produce richer data sets for operational decision-making, but also perform a function, on an automated or partly automated basis, based on the information developed from those data sets.

In the case of both component automation pertaining to existing equipment and component automation pertaining to new equipment, the software contained in that equipment interacts with internal and in some instances, external data sets as well as analytical software that initiates an action or informs human expert judgement. The broad categories of component automation are summarised in the following figure.
Component Automation and a Big Data Operating Environment

Big Data refers to datasets the size of which is beyond the ability of typical database software tools to capture, store, manage and analyse.

The volume and diversity of data produced by organisational ICT systems is currently growing at 40 percent per annum and is expected to increase by 44 times between 2009 and 2020. Large volumes of diverse operational data have played an important role in optimising operations in the resources industry for some time. However, the proliferation of component automation throughout the spectrum of minerals operations, will continue to drive a shift from conventional mine operations management to a form that is more data intensive across a wide range of minerals operation functions.

In 2013, the big data industry turned-over US$18.6 billion, representing a 58 percent growth rate over 2012 and is expected to achieve sales of US$50 billion by 2017. Much of the data produced by resources operations with a high intensity of component automation is machine-generated data, which is produced in much larger volumes than most other sources of big data. In the case of resources operations, this data is also characterised by significant variety, velocity and variability, and includes:

- Geological and geospatial data
- Maintenance and asset information
- Process control and automation data
- Environmental data
- Production data
- Financial data
- Supply chain data

The Australian resources industry is positioning itself to derive significant benefit from the deployment of component automation, the ICT systems that supports that component automation and the resulting big data operating environment\(^1\). While the immediate impact of big data on the resources industries will likely be less than sectors for which data has always been core business, compared to other sectors of the economy, the Australian resources industry compares favourably in terms of having a data driven mindset, the availability of data

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\(^1\) IBISWorld (2012), *A Snapshot of Australia’s Digital Future to 2050*
and relative ease of data collection. The resources industry does perform less well with respect to IT intensity when compared to other sectors. However, this will likely be addressed in the short to medium term by the introduction of increased component automation. The biggest challenge for the resources industry with respect to big data is that it performs poorly compared to other industry sectors with respect to the availability of ICT and ICT analytical talent. Surveys suggest that many resources companies are not investing in the big data talent capability that will be necessary to capture the potential benefits a big data operating environment presents.

**Implications for Workforce, Skills, Training and Education**

The increased incidence of component automation will introduce new technologies to the resources industry, albeit most of these technology platforms are relatively mature platforms in other sectors.

When compared to other sectors of the Australian economy, the mining industry employs relatively few ICT managers, ICT professionals and ICT technicians and related trade persons. The traditional mining industry workforce skill profile would arguably not be able to support many of the new technologies being introduced through component automation. This is likely to change over the short term as operations build their ICT capacity to support component automation.

The new roles of automation technician, mechatronics and production manager and process optimisation experts as identified in the initial study\(^2\) will continue to be increasingly required by the resources industry to support an increasing incidence of component automation. By virtue of the fact that component automation will achieve a broader and more rapid rate of penetration than fully automated systems, it is possible the demand for these skills may grow quite rapidly.

The event of component automation will have limited impact on the number of tradespersons employed on mining operations, as many of the routine maintenance functions required by skilled tradespersons will remain. However, electrical trades, networking technicians and automation technicians will likely be in increasingly greater demand.

Resource project operators are reporting that new apprentices are entering the workforce with:
- At least a familiarity with the new technologies being deployed on resources projects;
- Reasonably well developed understanding of base level mathematics, science and engineering concepts; and
- Problem-solving mindsets.

It has been observed by resources project operators that this has resulted in a generation of tradespeople who are able to quickly develop skills either on-the-job and/or through OEM training to support incremental new technologies that emerge in their field of expertise.

The increasing requirement for networking and automation technician roles will likely be met by evolving certificate level curriculum, new diploma level qualifications and post-trade programs offered by mining equipment OEMs. Furthermore it is likely that tradespersons such as

\(^2\) Australian Venture Consultants (2012), *Rise of the Machines? Adoption of Automation Technology in the Australian Resources Industries and its Implications for Vocational Education and Training and Higher Education*, Resources Industry Training Council
electricians will develop skills either on-the-job, or through supplementary training that allows
them to perform at least some of the functions of networking and automation technicians.

Because component automation presents a significant challenge with respect to systems integration, data fusion skills typically possessed by mechatronics engineers, computer programmers and systems analysts will also likely the subject of greater demand.

It is likely undergraduate and graduate electronic and mechatronic engineering programs will continue to meet the professional technical skill needs of an evolving mining industry that is characterised by a higher incidence of component automation.

A new emerging role that has been identified by this study is that of a Big Data analyst. As the resources industry becomes increasingly automated and the associated equipment produces large volumes of diverse operating data, the industry will enter a Big Data operating environment. The effective uses of Big Data is reliant on Big Data analytical expertise that in the context of a resources industry operation is founded in the disciplines of statistics, pure mathematics, computational chemistry, machine learning and organisational systems analysis. The resources industry will compete with other sectors for these relatively rare skillsets.

The relatively poor trend in STEM education in Australia does not present an optimistic case for increasing numbers of graduates from Australian universities that can meet this demand. However, the trend in STEM education in many Asian nations3, suggests that Asia may be a source of supply for this emerging skills requirement. It should be noted that because data is mobile, it is possible that some Big Data analytical tasks may not require the data analyst to be in-situ. As such, it may eventuate that in the case of Australia some Big Data services are imported.

Skills Relationships with Other Industries

With respect to technology, the industries the resources industry arguably has the closest technology sourcing relationship with is the defence industry. This is not surprising given the commonality in field deployment conditions, requirement for high levels of systems reliability and high OHS standards. The resources industry also has a technology sourcing relationship with the automotive industry that stems from the intensive deployment of wheeled vehicles in most mining operations.

Defence force technicians and tradespersons not only have skills relevant to the type of technology that is typically deployed in the resources industry, but also usually possess a work ethic and OHS culture that is desirable to the industry and are typically comfortable working in remote locations for periods of time.

The Australian Defence Force employs a total of 105,000 permanent and reservist defence force staff and Australian Public Service staff. Approximately 50 percent of Australian Defence Force Staff are employed in technical roles.

The Australian Defence Force is a training intensive organisation, operating four Registered Training Organisations to deliver training and assessment across 24 training programs. Because there is limited opportunity for lateral recruitment in the Australian Defence Force, retention of staff in which a training investment is made is critical to the Australian Defence Force sustaining capability.

The highest separation points for Australian Defence Force personnel are the first year and the year corresponding to the completion of the first term. In technical roles that are relevant to resources industry automation, approximately 30 percent of personnel leave the Australian Defence Force prior to completion of their first term. Indeed there is considerable skills overlap with the technical skills needs of an increasingly automated resources industry and the skills developed by training programs associated with the Australian Defence Force and the defence industry more broadly.

Recent announcements by Holden, Toyota and Ford that they will be ceasing vehicle manufacturing in Australia may have several impacts on automation in the Australian resources industry:

- When the plants close, some technical positions that are made redundant may be absorbed into technology deployment and maintenance roles at mining operations or more likely, within OEMs that develop, sell and support automated mining equipment; and
- Some, if not many, of the 200 domestic component, tooling, design and engineering firms that have supported the Australian automotive manufacturing sector most likely also support the resources sector. The closure of the automotive manufacturing sector may challenge the economic sustainability of some of the component, tooling, design and engineering firms thus weakening the sector’s capacity to support automation in the resources industries.

There is scope to explore better integration of technology transfer, technical training and employment opportunity between these industries to the mutual benefit of the sectors.
Background

In 2012, the Resources Industry Training Council (RITC) commissioned Australian Venture Consultants (AVC) to undertake a study investigating the level and trajectory of adoption of automation, remote control and systems integration technologies in the various sectors of the Australian resources industry, and to assess the current and likely future impact of the adoption of these technologies on the skills, training and higher education needs of the industry. The report from this study, *Rise of the Machines? Adoption of Automation Technology in the Australian Resources Industries and its Implications for Vocational Education and Training and Higher Education* was published in late 2012 and is available from the RITC.

The key findings of this study are summarised in the next section and Appendix 1 of this report. The central conclusion to this study was that for a range of economic and practical operational reasons, fully or close-to-fully automated resources operation systems are unlikely to become commonplace in the foreseeable future. However, the industry is currently experiencing relatively rapid penetration of sub-fully automated, or what is termed component automation systems, throughout the value-chain.

Component automation refers to automation, remote control and systems integration that occurs at a discrete systems component level rather than across the system as a whole. The most significant outcome of the rapid growth of component automation in the resources industry is the proliferation of mostly machine generated data that is produced from this component automation that can then be used to optimise operations.

The RITC has commissioned AVC to undertake a supplementary study exploring in more detail the adoption of component automation in the Australian resources industry and the implications of this phenomenon on skills requirements and training. Because automation is less commonplace in the mining industry than in the petroleum industry, the principal focus of this study is component automation in the mining industry.

This report is the output from that study.
Key Findings of Rise of the Machines

As discussed in the previous section of this report, the study that is the subject of this report is supplementary to a previous investigation\textsuperscript{4} into the event of automation in the Australian resources industry.

Automation can be broadly defined as the intelligent management of a system, using appropriate technology solutions, so that operations of that system can occur without direct human involvement\textsuperscript{5}. The term automation is used somewhat clumsily in industrial applications to describe systems and processes that are characterized by a range of direct human involvement intensity, including processes and systems that have high levels of human involvement through remote control. It is also used to describe the application of information and communication technologies (ICT) to achieve integrated operations.

The principle driver of adoption of automation in the resources industry is its positive impact on productivity (including OH&S). The impact of automation on productivity is summarised in Figure 1 below.

![Figure 1](image)

**Figure 1 – The Key Drivers of Adoption of Automation in the Resources Industry**

Perhaps the most important aspect of automated mining and petroleum production systems is the enormous amount of operating data that is produced by these systems. This creates the opportunity to centralize the monitoring and control of all the processes that comprise the operation to a single physical location. The ability to locate some front-line workers to a central, and increasingly remote, Operations Centre (OC) where they can apply their knowledge to analyzing and interpreting operational data streams from sensors attached to equipment in the field, historical and real-time operational data from across the operation, and other third

\textsuperscript{4} Australian Venture Consultants (2012), *Rise of the Machines? Adoption of Automation Technology in the Australian Resources Industries and its Implications for Vocational Education and Training and Higher Education*, Resources Industry Training Council

\textsuperscript{5} Mining Industry Skills Centre (2010), *Automation for Success*
party data sets, creates a decision environment for effective and efficient problem solving, and opportunities to optimize operations that has not previously existed in many sectors of the resources industry.

As there are general drivers of a decision to adopt automation in the resources industry, there are also general detractors to that decision. Principally, these are a set of related factors that potentially have a negative impact on project finance and/or operational risk. This is illustrated conceptually in Figure 2.

**FIGURE 2 – KEY DETRACTORS TO THE ADOPTION OF AUTOMATION IN THE RESOURCES INDUSTRY**

The primary reason that component automation is being adopted more readily than more comprehensive systems automation is that the adoption of component automation presents less project finance and operational risk, whilst still delivering significant productivity benefits, including those associated with operations centres.

As automation, including component automation, is progressively adopted by the resources industry, new technologies will be deployed that are not supportable by the current resources industry workforce skill base, particularly in the case of the minerals industry. The culture of operations that adopt extensive automated systems will change dramatically, again, particularly in the case of the minerals industry. The new culture will be one that is based on a higher incidence of remote control, workforce diversity and integrated, multidisciplinary, data-rich problem solving.

There is no doubt that automation will render certain roles in resources operations redundant as it has in other industries. However, there is little evidence to suggest it will result in significant reduction in overall employee numbers. Obvious candidates for redundancy are operators of the equipment that becomes automated, such as drill rigs, loaders, haul trucks and trains. However, even in these obvious cases, some of that workforce will most likely be retrained to
operate equipment or sets of equipment remotely, and to oversee components of the automated system. Some unskilled and semi-skilled roles may also be replaced by automation.

Importantly, the event of automation is unlikely to result in a significant reduction of tradespersons that are employed on a conventional resources operation, as most of the technical issues addressed by tradespersons will remain.

While the precise impact of automation on workforce size and structure is not entirely clear, there is general consensus among operators that the following three roles that are not usually associated with resources industry, particularly mining operations, but are commonplace in other automated environments, will become increasingly important operational roles in the resources industry:

- **Automation Technician**
  The role of an automation technician is to build, install and maintain automated machinery and equipment. It is largely a systems integration role, with electrical tradespersons still being required to perform functions such as wiring and mechanical tradespersons still required to address mechanical issues. If deployed on an operating environment today, it is expected that an Automation Technician would be heavily reliant on support or direction from other experts (engineers and tradespersons) to perform many of the tasks.

- **Mechatronics Engineer**
  Mechatronic technologies are central to field robotics and the application of automated and remote control systems to resources industry operations. Mechatronics engineering is a multidisciplinary field that combines electrical, mechanical, computing and software engineering to create expertise in designing, building, deploying and maintaining electromechanical devices such as robotics. A particular skill set that is common to mechatronics engineers that is crucial to many resources operations automation programs is data fusion expertise. Because highly automated resources industry operations produce enormous volumes of data from heterogeneous data streams, the ability to write software code that can interpret and integrate those heterogeneous data streams is critical to not only the operation of automated systems, but also optimizing their benefits.

- **Operations Optimisation Manager**
  As resources operations become more automated and the immediate benefits of the automation program are realized, significant additional benefits can be attained through optimization, as has been the experience of other largely manual processes that have achieved high levels of automation. This role applies expertise in logistics and process optimization to achieve optimal whole of operations productivity and other benefits, and is performed by an operations optimization manager.
The Machine’s Continue to Rise?

The Rise of the Machines? study notes that fully automated robotic systems are most commonplace in highly structured processes that demonstrate limited operational variance such as manufacturing lines in the automotive and electronics industries. In order to set context for the discussion of component automation in the Australian resources industry, it is worthwhile noting more recent trends in automation in other industries.

As discussed in Rise of the Machines?, robotic and ICT technology has and continues to dramatically change global industrial operations. From the first deployment of robotic technology in the early 1960s, the worldwide stock of operational industrial robots has grown to an estimated population of between 1,235,000 and 1,500,000 units in 2012. It is estimated that global robot sales have grown from 55,000 units in 1994, to 100,000 in 2004 and 160,000 units in 2012. In 2012, the total value of the robotics market, including hardware, software, peripherals and systems engineering was estimated to be US$26 billion.

Demand for industrial robots remains dominated by the automotive manufacturing industry, albeit its share of total demand is decreasing. In 2012 the automotive industry accounted for approximately 40 percent of total demand for industrial robots. The second largest market is the electrical/electronics manufacturing market comprising computers and computer accessories, radio, television, communication devices, medical devices and precision and optical instrumentation manufacturing. This market accounted for 21 percent of demand in 2012. Other markets such as laboratory robots are gradually growing in size.

Consistent with the dominance of the automotive and electrical/electronics manufacturing industries in the demand for industrial robots, the main automotive electrical/electronics manufacturing economies of Japan, China, United States, Republic of Korea and Germany are the main markets for robotic technology. This is illustrated in Figure 3 below.

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6 It is generally recognised that the automation of manufacturing processes through the application of robotics commenced in 1961 when General Motors installed a 1.8 tonne robotic arm known as Unimate to its production process.
7 International Federation of Robotics (2013), World Robotics 2013, VDMA Verlag Robotics and Automation
8 International Federation of Robotics (2013), World Robotics 2013, VDMA Verlag Robotics and Automation
9 International Federation of Robotics (2013), World Robotics 2013, VDMA Verlag Robotics and Automation
10 International Federation of Robotics (2013), World Robotics 2013, VDMA Verlag Robotics and Automation
11 International Federation of Robotics (2013), World Robotics 2013, VDMA Verlag Robotics and Automation
In 2012, the global average robot density was 58 robots per 10,000 employees. Not surprisingly, robot density tends to be high in countries that are characterised by significant automotive and electronic/electrical manufacturing industries such as Republic of Korea (396 robots per 10,000 employees), Japan (332 robots per 10,000 employees) and Germany (273 robots per 10,000 employees). Australia’s robot density has improved over recent years to be slightly above the global average, primarily as a result of increased investment in Australia’s automotive industry that was a response to government subsidies. Recent closures of automotive manufacturing operations in Australia will likely see Australia’s robot density decrease in the coming years. Potential implications of the demise of the Australian automotive manufacturing industry on industrial technology in Australia is discussed in a later section of this paper.

Global demand for industrial robots is expected to grow at approximately 5 percent per annum to 2016, at which point total robot shipments are expected to reach 192,000 units. Robot shipments in 2013 in North America alone, indicate that this growth will be achieved.

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12 Robot density is measured as the number of multipurpose industrial robots per 10,000 persons employed in the manufacturing industry
13 International Federation of Robotics (2013), World Robotics 2013, VDMA Verlag Robotics and Automation
As illustrated in Figure 4\textsuperscript{15} below, it is expected that demand will continue to be driven by automotive and electronics/electrical manufacturing economies.

**Figure 4 - Expected Global Growth in Multipurpose Industrial Robot Shipments**

This growth will see the global operational stock of multi-purpose robots reach 1.66 million by 2016. The largest increase in operational stock will be, with the exception of Japan and Germany, associated with the established automotive and electronic/electrical manufacturing industries, as well as the emerging automotive and electronic/electrical manufacturing industries in China and South East Asia. This is illustrated in Figure 5\textsuperscript{16} below.

**Figure 5 – Expected Growth in Operational Stock of Multipurpose Industrial Robots**

\textsuperscript{15} International Federation of Robotics (2013), *World Robotics 2013*, VDMA Verlag Robotics and Automation

It is clear from this analysis that for the foreseeable future robotics oriented automation will continue to be the domain of structured industrial processes such as manufacturing lines that are characteristics of the automotive and electronics/electrical manufacturing industries. Even in the resources industries a main application of robotics technology is in sampling laboratories where large numbers of repetitive geological and chemical assaying procedures are frequently conducted by laboratory robots such as ‘Roxanne’ at Alcoa’s refinery operations in Kwinana.
Trends in Automation in other Industries

Even though highly automated robotics based automation systems remain largely confined to highly structured, repetitive processes, there has been a long-standing recognition by industrial process professionals that:

- Reduced variance in operation systems and improved process performance generally is dependent on the generation of high quality process data that can be used to optimise processes and that this data will increasingly be produced from automated equipment; and
- That there is a significant gap between processes and components of processes that can be automated and those processes and components of processes where it makes economic and practical sense to automate.\(^{17}\)

Determining which aspects of an overall process stand to benefit the most from automation and the ultimate impact of automating that aspect on the overall performance is a predicament that faces most sectors of the Australian resources industry, as well as many other industries.

The Rise of the Machines? study presented a detailed case study, examining the implementation of field robotics based automated systems at a seaport container terminal. The study noted that field robotics based automation of seaport container terminals had not been widely adopted by the global seaport container terminal industry, a situation that remains the case.

Globally, containerised freight has been a major driver of increased trade. For example, a recent study of a sample of 22 industrialised countries demonstrates that external trade in those countries grew by 292 percent within the first 20 years of the event of containerisation of ports.\(^{18}\) This growth is expected to continue, driven primarily by the logistics needs of the rapidly growing Asian and African economies. Indeed, global container throughput is expected to almost double during the period 2012 to 2020, when it will reach approximately 1 billion TEUs per annum.\(^{19}\)

Despite the rapid historical and projected growth of global container traffic and the clear benefits that automation can deliver a seaport container terminal (at least one of the scale of Fisherman’s Island), there remain only a handful of operating and planned automated terminals around the world.\(^{20}\)

The following discussion endeavours to explain why, from an economic and operations perspective, the adoption of seaport container terminal automation has not been as rapid or as prolific as one might have thought given the significant benefits delivered by the automation program at Fisherman’s Island.

This analysis is pertinent to this study because it helps explain why, in many industrial applications, component automation is often preferable to a large-scale automation system.

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19 American Council of Logistics Management
20 American Council of Logistics Management
Automation in Seaport Container Terminals

**Fisherman’s Island Revisited**

The *Rise of the Machine?* report presents a case study that illustrates and discusses issues associated with the adoption of a high level of automation through the application of field robotics at a sea container terminal operated by Patrick (now a division of Asciano) at the Fisherman’s Island container facility at the Port of Brisbane, Australia.

The automated container handling facility at Fisherman’s Island revolves principally around a proprietary automated straddle carrier technology known as Autostrad. The 38 hectare container yard and three berths situated along a 900 metre quay-line are serviced by a fleet of approximately 30 Autostrad units that deliver an annual capacity of approximately 1.2 million Twenty-foot Equivalent Units (TEU) per annum.

The automated terminal at Fisherman’s Island has received a range of industry awards including the coveted Lloyds List Industry award for “best terminal” as voted by the shipping company users of the Australian waterfront in 2010. This is not surprising given the significant impact that the automated container handling system deployed at Fisherman’s Island has on operational KPIs that are critical measures of seaport container terminal performance:

- **Occupational Health and Safety**
  The resulting elimination of ergonomic injuries that are common to operators of straddle carriers and the removal of workers from 80 percent of the terminal operating area resulted in a reduction in the annual Loss Time Injury Frequency Rate from approximately 180 to 4, as well as a reduction in the workers compensation insurance premium from A$1.0 million to A$0.2 million.

- **Productivity**
  Implementation of the system resulted in significant productivity improvements that stem from improved regularity and predictability of stevedoring operations, increased crane movement rates, increased number of cranes, reduced size of crane gangs, reduced size of the overall workforce, reduced electricity costs associated with reduced lighting requirements and reduced road maintenance requirements.

- **Freight Damage**
  The AutoStrads move and stack containers from the quay line into holding yards and onto vehicles and back to quay cranes with an accuracy of better than 20mm. As a consequence, freight damage in the automated environment has been significantly reduced.

**The Rise of Multimodal Logistics Systems**

The term *multimodal transport* refers to the transport of goods from one point to another via more than one mode of transport (e.g. sea, air, road and/or rail) whereby the goods themselves are not discharged and re-loaded at the trans-shipment point but remain in a loading unit such as a container or trailer. *Multimodal logistics* describes the system that

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21 Deloitte (2012), *Intermodal and Multimodal Logistics Knowledge Paper*
interconnects different modes of transport that give effect to multimodal transport into a single integrated process that ensures an efficient and cost-effective door-to-door movement of goods under a single transport operator known as a multi-modal transport operator and a single transport document.

Multimodal logistics plays an increasingly fundamental role in world trade and containers are the backbone of the multimodal logistics industry. A multimodal logistics hub is a facility (or network of facilities) that gives effect to multimodal transport and logistics. By virtue of optimal access to road, rail, pipeline, short-sea, river and air transport infrastructure, modern seaports tend to perform this function.

More detail on the growth of multimodal logistics and its importance to efficient global trade is contained in Appendix 2.

Complexity of Multimodal Logistics Hubs

While seaport container terminals perform an important hub role in the multimodal logistics system, they do only represent one component of the value chain.

In fact, multi-modal logistics operations substantially increase the complexity of the logistics function, particularly in the case of high volume fast moving facilities. There are five key determinants of multi-modal logistics port performance:

- **Maritime Forelands**
  Maritime connectivity refers to both the number of connections as well as the place of the specific port in networks (i.e. centrality). Maritime connectivity is essential for competitive ports as connectivity determines the frequency and reach of shipping services. Ports with extensive maritime connections can offer shippers more direct services and speedier delivery of cargo.

- **Port Operational Efficiency**
  The main performance metrics of a port assess the performance of cranes, berths, yards, gate and gangs in terms of utilisation rates such as TEUs per year per crane, vessels per year per berth, TEUs per year per hectare and container hours per shipping lane, as well as productivity measures such as TEU moves per crane hour, vessel service time, truck time in terminal and number of gang moves per man-hour. Vessel turnaround time is another key performance metric.

- **Land Productivity**
  Modern multimodal port terminals require a relatively large amounts of increasingly valuable land. At the minimum, a functional port container requires a several berths for handling various ships at the same time, a quay-side for ship to shore operations, a container transfer area, a storage area, an area for delivery and receiving, connected to road and rail lines, depot for empty containers, a customs area and a truck waiting area. In many cases, land is also required for logistics activities such as distribution centres and for industries that benefit from proximity to port.

- **Labour Relations**
  In many jurisdictions, stevedoring industries have a long history of industrial disputes and strong employee unions. For ports operating in these jurisdiction in particular, harmonious and sensible industrial relations is a key criteria for port productivity.

- **Hinterland Connectivity**
  The goal of multi-modal ports is to integrate the port system with the multimodal transportation network to improve market access, fluidity of trade and integration in
an industrial network. In order to give effect to this, a seaport container terminal must have efficient interfaces with hinterland river, rail and/or road transport networks, as well as the commercial entities that manage hinterland logistics operations on these networks. Furthermore, these commercial logistics providers and the river, road and rail infrastructure that use must be efficient.

While an automated seaport container terminal can have a significant positive impact on land productivity and port operational efficiency, the impact on labour relations can be either positive (as was the case with Fisherman’s Island) or negative as is currently being experienced at Port Botany. The impact of an automated seaport container terminal is far less with respect to maritime forelands and hinterland connectivity, albeit the efficiency of the seaport container terminal will impact on the loading-unloading costs associated with shipping and road or rail interconnectivity.

**Managing Intermodal Complexity and the Technology Paradigm**

At the most basic level creating an operating environment for an efficient intermodal or multimodal transport system typically requires three key issues to be addressed:

- **Infrastructure Development**
  Intermodal and multimodal transport builds on the operational efficiencies of the transport system. This obviously includes key river, road and rail transport corridor infrastructure but also infrastructure that facilitates compatibility between modes that results in decreased dwell times, less friction cost and less pilferage. Without such infrastructure the incremental benefits of intermodal transport will be negligible.

- **Regulatory Reforms**
  In some jurisdictions, the growth of intermodal transport may require changes to customs procedures and export-import procedures. In the case of the domestic component of the system, changes in Cabotage laws and octroi levies may also be required.

- **Investment in Technology**
  An intermodal or multimodal operator enters into a single contract with the shipper, but multiple contracts with transporters, customs agents, ports, airports, railways, warehouse operators and other related entities. The voluminous documentation requirements and need to coordinate with a number of parties creates a need for appropriate information technology support. Additionally, the transport and warehousing technology must itself be up-to-date to facilitate accurate tracking of shipments and reduce logistics cost and time.

Of these three factor, technology has become critical to efficient performance of a multimodal logistics network. Multi-modal container terminals are dynamic environments in which a large number of timely decisions need to be made and continuously review in accordance with the changing conditions of the terminal system. Optimal performance of the terminal is a function of:

- Efficient loading and unloading of ships on the quay line and at the inland waterways terminal;
- Efficient loading and unloading of trucks and trains at the hinterland despatch terminal; and

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Deloitte (2012), *Intermodal and Multimodal Logistics Knowledge Paper*
• Rapid and accurate movement of containers to and from loading and unloading points and within the terminal yard.

The productivity of these movements are primarily dependent on sequencing and re-sequencing and balancing the multistage container transfer process, operating strategic, physical layout of the terminal and storage processes. At the container terminal, ICT systems have become critical in managing the complexity of these sequencing decisions, supported by more intelligent equipment such as GPS controlled gantry cranes, quay planning software, RFID tracking of cargo and automated routing of port vehicles.

However, in the context of the overall multimodal logistics system, the complexity of these movements is significantly exacerbated by the need for efficient interconnections with the different transport modes, a criteria that is essential to a competitive multi-modal logistics network. In such an operating environment information availability, visibility, operational flexibility and scalability are critical to a successful logistics function. The growing complexity of logistics networks has rendered technologies such as Intelligent Transport Systems (ITS), which involves the use of advanced ICT to achieve a reduction in transport vehicle congestion and other cost saving benefits and Wireless Vehicle Networks which enable vehicles in close proximity to communicate with each other are becoming increasingly commonplace.

The main specific technologies that support better decision-making in multimodal logistics systems are summarised in Table 1 below.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Computing and Software-as-Service</td>
<td>Facilitates a low up-front investment in infrastructure required to support and ITS that is scalable and facilitates relatively simple integration of data from a wide range of participants in the supply chain.</td>
</tr>
<tr>
<td>Global Positioning System</td>
<td>Ability to identify the exact location of a vehicle and consignment facilitates more effective planning of delivery and connectivity, evaluate and reward driver behaviour and locate and recover disabled vehicles more efficiently.</td>
</tr>
<tr>
<td>Radio Identification Frequency</td>
<td>Facilitates tracking, monitoring, reporting and managing products, documents, assets and people more effectively and efficiently as they move between locations along the supply chain.</td>
</tr>
<tr>
<td>Enterprise Resource Planning</td>
<td>Provides visibility through the supply chain allowing the sharing of data from functions such as purchasing, warehousing and sales.</td>
</tr>
<tr>
<td>Mobile Technology</td>
<td>Mobile connected smart phones and tablets facilitate data rich communications with operators of mobile equipment.</td>
</tr>
</tbody>
</table>

Table 1 – Technologies that Enable Intelligent Transport Systems

Kozan, E. (XXX), ‘Container Transfer Logistics at Multi-modal Terminals, Queensland University of Technology School of Mathematical Sciences, Brisbane

Deloitte (2012), Intermodal and Multimodal Logistics Knowledge Paper
While an efficient seaport container terminal is critical to the competitiveness of the overall multimodal logistics system, it is often the hinterland transport systems that are the critical bottleneck. Examples of this are India’s logistics industry and the Port of Hong Kong. The following two sections discuss these cases.

**India’s National Logistics Industry**

During the period 2003 to 2013, the Indian economy grew at an average rate of 7.6 percent\(^{25}\). While this growth has primarily been driven by India’s service sector, manufacturing and merchandise exports have also grown considerably.

Supporting this economic growth is an Indian logistics industry that employs approximately 45 million people, with estimates of turnover ranging from US$90 billion to US$225 billion per annum\(^{26}\). However, despite its size the Indian logistics industry substantially underperforms compared to other countries, with India ranked 54 out 160 countries according to the World Bank International Logistics Performance Index in 2014\(^{27}\). Furthermore, in 2012, the Indian logistics system cost approximately 13.5 percent of GDP compared to a global average of 7.5 percent of GDP in the developed world\(^{28}\).

As illustrated by the data in Table 2\(^{29}\) below, while congestion at India’s ports is clearly part of the problem, capacity and congestion in the road and rail network presents a significant bottleneck in the productivity of India’s multimodal logistics network. This is exacerbated by inefficient and inconsistent trade, as well as goods and services regulation between the provincial jurisdictions that comprise India.

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\(^{25}\) International Monetary Fund (2013), *World Economic Outlook Database*

\(^{26}\) PHD Chamber of Commerce and Industry and European Business and Technology Centre (2011), *Multimodal Logistics in India: An Assessment*

\(^{27}\) The World Bank (2014) Logistics Performance Index

\(^{28}\) Report of the Indian Foundation of Transport Research and Training IN: Deloitte (2012), *Intermodal and Multimodal Logistics Knowledge Paper*

\(^{29}\) Deloitte (2012), *Intermodal and Multimodal Logistics Knowledge Paper*
<table>
<thead>
<tr>
<th>Mode</th>
<th>Details</th>
<th>India</th>
<th>Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>Average truck speed (km/h)</td>
<td>25-35</td>
<td>60-80</td>
</tr>
<tr>
<td></td>
<td>Average distance covered by a truck per day (km)</td>
<td>250</td>
<td>400-450</td>
</tr>
<tr>
<td></td>
<td>Total four lane highway length</td>
<td>7,500</td>
<td>China – 34,500</td>
</tr>
<tr>
<td>Ports</td>
<td>Turnaround time</td>
<td>4.67 days (major ports 2010-11)</td>
<td>7 to 10 hrs (Hong Kong)</td>
</tr>
<tr>
<td></td>
<td>Pre-berthing delays</td>
<td>55.7 (major ports 2010-11)</td>
<td>3 to 5 (Hong Kong)</td>
</tr>
<tr>
<td></td>
<td>Average output per ship berth day ('000 tons)</td>
<td>10.735</td>
<td>45-60 (Australia)</td>
</tr>
<tr>
<td>Rail</td>
<td>Total double line (km)</td>
<td>17,400</td>
<td>26,400 (China)</td>
</tr>
<tr>
<td></td>
<td>No. of locomotives</td>
<td>8,867</td>
<td>18,500 (China)</td>
</tr>
<tr>
<td></td>
<td>No. of freight wagons</td>
<td>2.35 million</td>
<td>5.78 million (China)</td>
</tr>
</tbody>
</table>

Table 2 – Indian Transport Infrastructure – A Global Comparison

Any multi-modal productivity dividends gained through seaport container terminal automation in India, would be substantially diluted by the poor productivity associated with hinterland logistics, detracting from the decision to invest in seaport container terminal automation.

Port of Hong Kong

Historically, the Port of Hong Kong has been the transport and logistics hub for southern China, handling approximately 70 percent of cargo in and out of southern China. Since 1972, the Port of Hong Kong has grown 18-fold. Currently, approximately 32,000 ocean going vessels and 170,000 river vessels visit the Port of Hong Kong annually. According to the Hong Kong Shipowners Association, its members own or manage 9 percent of the total global fleet.

As illustrated in Figure 6 below, Hong Kong is the world’s third largest container port and accounts for approximately 6 percent of the containerised traffic of the world’s 50 largest container ports. Approximately 80 percent of cargo traffic through the Port of Hong Kong is container traffic, with liquids and bulk cargo accounting for the balance.

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31 World Shipping Council (2014), Top 50 Container Ports
Chinese ports account for approximately 40 percent of the containerised traffic of the world’s 50 largest container ports and in recent times the Port of Hong Kong has faced increasing competition from the ports of Shenzhen and Guangzhou on the Chinese mainland.

The Kai Tsing Container Terminal at the Port of Hong Kong is the only container facility at Hong Kong Port that can accommodate Large Ocean Going Vessels (OGVs). The Kai Tsing terminal has a berth length of 5,000 metres, space for 14 berths and a total area of 1.4 million square metres. It has a land productivity factor of 60,000 TEU which is approximately 10,000 TEUs above the average South East Asian port and 50,000 TEU above the average North American port.

Hong Kong is a gateway port, with a sea-to-sea transhipment rate of 30 percent, compared to a typical transhipment port like Singapore, where the transhipment rate is approximately 85 percent. Approximately, 40 percent of the cross-boundary container cargo into southern China from the Port of Hong Kong is transported by trucks, with the remainder by barge. The transhipment operation at the Kai Tsing terminal is supported by a midstream operation, whereby, weather permitting, containers are unloaded onto barges from ships in the anchorage for transportation to other facilities at the Port including the River Trade Terminal for transhipment to the Chinese mainland. This is a major source of congestion, but important in ensuring berthing time is minimised.

The Port of Hong Kong industrial cluster employs approximately 83,700 people. As illustrated in Figure 7 below, approximately half of these people are employed in the sub sector of land
transport and storage operations, a fifth in ship operations, a fifth in cargo services and approximately one tenth in port operations.

**Figure 7—Distribution of Employment in the Port of Hong Kong**

The main challenge facing the competitiveness of the Port of Hong Kong with respect to the Chinese mainland ports is improving the competitiveness of transport operations between the Port and the Mainland. Road haulage costs are estimated to add an additional US$300 per Forty Foot Equivalent Unit (FEU) when shipping to the United States through Hong Kong rather than a mainland port and US$200 on in-bound cargo. In 2006, the Hong Kong Government launched a Digital Trade Transport Network that provides an open neutral and secure e-platform for efficient and reliable information flow along the supply chain and piloted an On-Board Trucker Information System.

The sheer size of the Kai Tsing terminal (approximately 20 times the size of Fisherman’s Island) presents a challenge to developing and deploying automated terminal facilities. However, it is the hinterland connective productivity that is the main limiting factor to the performance of the Kai Tsing terminal, particularly in regards to its competitive position with respect to the mainland container terminal ports. Similarly in India, the largest productivity improvements are likely to be achieved through improving the efficiency of the hinterland road and rail networks and indeed, any improvement to port productivity will be substantially diluted by the hinterland bottlenecks.

This discussion is relevant to the context of adoption of automation in the resources industry as it supports the rationale that when considering an investment in automation, identifying relatively simple automation solutions such as ITS, that target key bottlenecks, rather than the

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entire system can deliver significant benefit. It is this paradigm that is driving increased adoption of component automation in the resources industry over fully automated systems.
Component Automation in the Australian Resources Industry

Over the past five years, some operators of large, multi-mine bulk commodity operations such as the Pilbara mine, rail and port iron ore operations have made significant capital investments in equipment automation and systems integration from drilling and blasting functions, through in-pit haulage, processing, train transport and ship-loading, substantially controlled from a remote operations centre. As discussed in Rise of the Machines?, such investments in fully automated or close to fully automated mining systems present a favourable cost-benefit investment case for geographically dispersed, high throughput, bulk commodity operations where efficient logistics is a key determinant of overall project performance and high levels of automation and integration facilitate optimisation of that logistics network. However, for most other types of mining operations, developing a favourable investment case for investment in fully automated or close to fully automated systems will prove challenging.

The difference in operational scale, throughput and logistics intensity of the business model that renders total systems automation compelling is significant. In order to demonstrate order of magnitude, Table 3 below compares aspects of the mining systems of Rio Tinto’s Pilbara iron ore operations, which is the largest integrated mining operation in Australia, with that of Australia’s largest gold operation, KCGM’s Kalgoorlie Superpit. In addition to the obvious difference in mining operations scale, is the absence in the case of KCGM’s operations of post mine-gate logistics complexity.
Despite the fact that full automation of mining systems is unlikely to present an attractive cost-benefit investment case in the vast majority of operations, significant improvements in productivity can and is being captured through the application of component automation and systems integration to parts of the value chain that deliver attractive cost-benefit investment cases. As illustrated by the discussion on multimodal logistics systems in a previous section of this report, this is also the experience in other industries.

Arguably, the last major improvement in mining industry productivity occurred during the 1960s when larger mining equipment was developed to support economies of scale in large mining operations. The Pilbara iron ore industry was most certainly a beneficiary of the development of larger mining equipment. There has been some commentary that the next major step-change in mining productivity improvement will occur as the result of fully-automated mining systems. Indeed, this may prove the case for some Pilbara iron ore operators. However, it is more likely that more immediate and significant improvements in productivity in most sectors of the Australian mining industry will arise from the increased adoption of component automation and the range and volume of operational data that will be produced from the ICT enabled equipment that forms that component automation.

**Table 3 - Mining System Comparison – Rio Tinto Pilbara Iron Ore Operations and KCGM Superpit**

<table>
<thead>
<tr>
<th>Operational System</th>
<th>Rio Tinto Pilbara Operations</th>
<th>KCGM Superpit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Mines</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Total Mine Throughout</td>
<td>290mtpa (expanding to 360mtpa)</td>
<td>12.5mtpa</td>
</tr>
<tr>
<td>Current Mine Life</td>
<td>30+ years</td>
<td>16 years</td>
</tr>
<tr>
<td>Number of Face Shovels</td>
<td>n.a.</td>
<td>4</td>
</tr>
<tr>
<td>Number of Haul Trucks</td>
<td>150</td>
<td>40</td>
</tr>
<tr>
<td>Number of Water Trucks</td>
<td>?</td>
<td>10</td>
</tr>
<tr>
<td>Number of Trains</td>
<td>48</td>
<td>0</td>
</tr>
<tr>
<td>Number of Locomotives</td>
<td>173</td>
<td>0</td>
</tr>
<tr>
<td>Number of Train Wagons</td>
<td>10,500</td>
<td>0</td>
</tr>
<tr>
<td>Length of Track</td>
<td>1,500km</td>
<td>0</td>
</tr>
<tr>
<td>Number of Ports</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Number of Berths</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Number of Ship Loaders</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Length of Conveyor Systems</td>
<td>113km (primarily at port)</td>
<td>4km (mine head to processing)</td>
</tr>
</tbody>
</table>

31
What is Component Automation

Component automation refers to automation, remote control and systems integration that occurs at a systems component level rather than across the system as a whole. This definition encompasses a wide range of automation initiatives from enabling existing equipment with a wide range of sensors and networking that equipment such that more informed decisions pertaining to the operation of that equipment can be made, through to new automated equipment that performs a specific function. Eventually, component automated systems may become networked, giving effect to a fully integrated system. However, in many cases, for the foreseeable future there may not be an acceptable investment case for this integration.

Drivers of Component Automation in the Australian Resources Industry

Component automation occurs because resources operations make commercial decisions pertaining to the productivity dividends they receive as a portion of the investment they make in automation. That is, investment in automation tends to occur in areas where the productivity dividend per dollar of automation investment is greatest.

The elements that comprise this productivity return that are favourable to component automation over fully or close to fully automated systems are summarised in the following Table 4.
<table>
<thead>
<tr>
<th>Driver of Favourable Productivity Returns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Capital Outlay</td>
<td>Designing, developing and deploying customised fully-automated mining systems represents a significant capital investment that must be competitive from a return-on capital perspective. This is particularly problematic for mining operations with relatively short mine lives. It also renders investment decisions more palatable in budget cycles that are often determined by commodity price cycles. The fact that component automation initiatives typically involve a smaller capital outlay means that the denominator in the return on investment algorithm is typically more favourable for a component automation investment.</td>
</tr>
<tr>
<td>Labour Productivity</td>
<td>In most cases partial automation will result in the equipment being able to be operated by a less skilled operator, thus reducing labour costs and increasing the pool of labour that can be deployed on the operating task.</td>
</tr>
</tbody>
</table>
| Capital Productivity                     | Significant improvements in overall capital productivity can be accomplished by achieving incremental improvements in capital productivity through different elements of the operating cycle that can be achieved through component automation rather than full automation. For example, Significant improvements to haulage productivity as measured by $/tonne of total haulage cost by optimising:  
  - The haulage route;  
  - Fuel loading and consumption;  
  - Idling time;  
  - Tyre wear; and  
  - Maintenance scheduling  
This can be achieved by equipping haulage equipment with various sensors and networking that equipment to an analytical system. Similarly very significant improvements in underground mine productivity could be achieved through automation that reduces expertise required within an underground drilling crew or time associated with the blast-evacuate-extract cycle. |
| Occupational and Safety Health            | Component automation can be used to remove people from that part of the process that presents an OHS risk anomaly, achieving the same OHS outcome without fully automating a system. |
| Operations Optimisation                   | Component automation mostly involves equipment and systems that take numerous measurements through a range of sensors, are ICT enabled and networked. The data produced by this equipment can be used to optimise the overall operation. |
| OEM Productisation                       | In response to a larger market for component automation than for customised, fully automated mining systems together with a realisation that component automation can be productised far more easily than customised automation system products, OEMs are investing heavily in component automation product development, rendering component automation more easily accessible for a wider range of operations. |

**Table 4 - Factors Contributing to a Favourable Productivity Return for Component Automation**
Challenges Associated with Component Automation

The choice to invest in component automation over a fully automated system also has challenges and consequences that need to be considered. These are discussed in the following subsections.

Productivity Stovepipes

The main challenge associated with component automation is the potential to create stovepipes in overall system productivity. For example, the impact of the productivity improvement on the overall operation that results from the component automation investment might be significantly diluted, or even lost, if downstream processes are unable to translate the productivity improvement generated by the component automation to an overall bottom-line improvement in productivity in the form of either increased revenues and/or decreased costs. This particular challenge is highlighted by the discussion on intermodal logistics systems in an earlier section of this report.

Systems Integration

Most component automation initiatives will deliver benefits by being integrated with other ITC systems such as the Enterprise Resource Planning platform. As more component automation initiatives are put into effect, in many cases it will be desirable to integrate those systems with each other so that they can share data. ICT enabled equipment from different OEMs will have different data integration standards.

For the following reasons, integrations standards for connecting different technologies that form component automation systems are yet to emerge:

- It is too premature in the automated mining equipment product lifecycle for a standard to emerge; and
- OEM competition for share of the various component automation markets demotivates OEMs to collaborate on a data integration standard

Some attempts to develop data integration standards have emerged over the past decade. An example of this is the International Rock Excavation Data Exchange which is a data exchange protocol for drilling equipment established between Atlas Copco, Barrick, Boliden, LKAB, Normet, Orica, Rio Tinto, Sandvik and Vale. While attempts to establish standardisation of software products in the resources industry can prove fruitful, in most cases software integration standards are determined by the product leader as the market matures.

Equipment Replacement Cycle

Traditionally, three main factors have driven equipment replacement cycles:

- Operating life of the equipment
  The operating life of mining equipment is highly variable and largely dependent on the operating environment. A haul truck chassis may have an operating life of up to 100,000 hours (approximately 18 years) and its engine and drive chain up to 30,000 hours (approximately 6 years). Most, but not all, larger operators will seek to change out equipment at approximately half of the operating life. This is in-part driven by the depreciation schedule.
• **State of the Used Equipment Market**
The used mining equipment market is primarily driven by commodity markets. High commodity prices lead to new production projects and increased output from existing projects, whereby demand for used equipment typically comes from mid-tier producers in mature provinces and a range of producers in lower cost jurisdictions. In times of decreasing commodity prices, more used equipment comes into supply as producers shed surplus equipment as the result of mine closures or reductions in output.  

• **New Equipment Requirements**
As operations progress through their lifecycles, operating conditions change, corporate strategy evolves and/or new OHS and environmental regulations come into effect. New equipment may be required to optimise operations, give effect to new strategy and/or meet the requirements of new regulations.

Component automation interacts with the equipment replacement cycle at two levels. Firstly, all things being equal, longer equipment replacement cycles that can result from more durable equipment potentially delays the replacement of older equipment with equipment that is ICT enabled. However, the drive to attain greater operating efficiencies can also compress the equipment replacement cycle as companies seek opportunities to replace older equipment with smarter equipment that enables them to optimise operations.

**Not All Sites are Suited**
As is the case with fully automated mining systems, the operating site at which the component automation systems are to be deployed must be suitable from a cultural, work-practice, skills base and operational layout perspective. The site must be physically and culturally able to accept, deploy and operate the system. However because component based automation is either additive to a conventional system or automates only a component of the overall system, it is less invasive than a fully automated system and as such is usually more easily implementable.

Regardless of the potential challenges presented by component automation, the elements of the component automation productivity dividend discussed in Table 4 above, combined with the fact that the smaller scale and less invasive nature of most component automation investment results in less associated financial and operational risk, means that investment in component automation will present a relatively more compelling case than full systems automation for most mining operations.

**Opportunities for Automation through the Value Chain**
The Rise of the Machines? study focused on the application of automation to the main mining industry activities of exploration, extraction, processing and transportation. Part of the remit of this study was to explore the potential application of component automation to processes upstream and downstream of those activities.

In most of these applications the opportunity to deploy highly automated equipment is limited by:

The diverse range of environments in which activities upstream and downstream of the core mining and processing activities occur, making the standardisation of operations difficult; and

The less frequent operating patterns for equipment in these applications that has the effect of diluting the capital utilisation case for equipment automation.

However, using ICT enabled equipment in a number of applications upstream and downstream of the core exploration, mining, processing and transportation functions can generate useful data that can be used to optimise the processes upstream and downstream of the core processes and the core processes themselves.

Potential Upstream Applications

Pre-competitive Data Set Integration and Interpretation

Over time enormous amounts of data has been collected from a wide range of organisations that is relevant to understanding geological and geotechnical phenomena and environmental context. This data is collected by government agencies such as Geoscience Australia, government environmental agencies, universities and other scientific organisations. It is also collected by commercial organisations that are not competitive. For example, seismic and/or electromagnetic data collected by an oil and gas exploration and/or production company can inform minerals exploration. While some of this data may be commercially sensitive, much of it is not, or at least becomes commercially insensitive over time.

This class of data, which is commonly referred to as pre-competitive data exists in a wide range of data forms in fragmented databases. The ability to aggregate and analyse data from these sources is improving dramatically with new data fusion and analytical software. This will increasingly result in greater insights to exploration targeting, environmental approvals processes and management, mine operations and processing improvements.

Initiatives to provide improved, more efficient access to pre-competitive geological and environmental data are typically driven primarily by the government and academic sectors (as is the case in Western Australia and Australia) and supported by industry participants that stand to be benefit from access to such data.

Mining companies will need to assess the benefits and risks associated with providing data to these initiatives. They will also need to consider how they assess the relevance and usefulness of the vast volumes of data that may become available from such initiatives and how they efficiently integrate relevant and useful data into their internal data management and decision-making systems (see subsequent section on big data).

Environmental Approvals

In addition to the significantly improved management and use of existing environmental data, the opportunity to substantially improve the productivity and accuracy of primary biodiversity surveys potentially resides in automated laboratory processes such as genetic array rapid assessment technology, which are potentially capable of identifying diversity and uniqueness based on samples of genetic material. Such technology would facilitate a more productive process than current morphology based assessments of diversity and uniqueness and render the industry less reliant on expert taxonomists who are in scarce supply, particularly during times of significant investment in new projects.
Mine Plan Design

Arguably one of the major factors in determining return on investment and lifetime productivity of a mining operation is optimisation of the mine plan so that the correct balance of operational flexibility and mine-site productivity is achieved, as much as is possible over the life of the mine. Simply by virtue of the wide range of market, geological and geotechnical uncertainties associated with any new mine, optimising the mine plan in this respect is very challenging.

Nevertheless, the ability to aggregate and analyse increasingly large quantities of data from internal and external data sources, combined with the ability to deploy more ICT enabled mining equipment and other forms of component automation creates an environment where the initial mine plan design will be better informed and as such potentially better able to be optimised for productivity, operational flexibility and overall investment return.

Potential Downstream Applications

Restoration and Rehabilitation

While some mining operations, such as mineral sands mines, conduct most restoration activity as the mining operations progress, for most minerals operations the vast majority of restoration and rehabilitation activity occurs at the end of the life of the mine, with most minerals operations carrying large balance sheet provisions to account for this cost.

While there is some commentary around the potential to apply a more ‘agricultural’ approach to restoration, the opportunity to apply any significant automation to the restoration process is limited by two factors:

- **Task Specificity**
  Mining in Australia takes place across very diverse landscapes and Australia is characterised by significant flora biodiversity, which often includes short range endemic species. This means that a significant component of the science that is used in designing and implementing restoration programs as well as the restoration program itself are very site specific.

- **Irregular and Limited Equipment Use**
  Because of the infrequency of most restoration programs, the capital utilisation argument that is fundamental to automation investment is significantly diluted.

However, opportunity exists for better harnessing and using data for designing and implementing restoration programs and monitoring the long term performance of restoration programs.

Types and Examples of Component Automation

Component automation covers a very wide range of automation, remote control and integrated operations technologies. Broad categories of component automation include:

- Existing types of mining equipment that has been ICT enabled with sensors and the ability to communicate with various systems that comprise the mining operation;
- Existing types of mining equipment that have been partially automated through technologies such as remote control;
- Equipment and processes that use various sources of internal and external data, often in conjunction with human judgement to optimise their operation;
New types of equipment that have been developed and deployed specifically for the purpose of developing richer data sets to inform operational decisions; and

New types of equipment that produce richer data sets for operational decision, but also perform a function, on an automated or partly automated basis, based on the information developed from those data sets.

In the case of both component automation pertaining to existing equipment and component automation pertaining to new equipment, the software contained in that equipment interacts with internal and in some instances, external data sets as well as analytical software that initiates an action or informs human expert judgement.

These broad categories of component automation are summarised conceptually in Figure 8 below and described, including by way of example, in the following subsections.
requirements, ensure the integrity of warranty claims and as an input to product improvement and new product design.

Integrated of data produced from this equipment with the operation or company’s Enterprise Resource Planning (ERP) databases and decision software results in significant longitudinal operational datasets on which simulations can be conducted to optimise overall operations, as well as the performance of individual pieces of equipment. Putting operational changes into effect can take the form of modifications to components of the equipment, equipment consumables or simply instructions to equipment operators designed to improve the operation of the equipment. Fleet Management systems often support employee reward programs targeted at efficient and safe operation of equipment.

Such ‘Fleet Management Systems’ are commonly used across a range of industries including logistics (see previous section on the multimodal logistics industry) and passenger transport industries.

Figure 9 below illustrates a high-level architecture of a basic mining fleet management system.

**Figure 9 – High-level Architecture of a Mining Fleet Management System**

**Partly Automated Equipment**

In the form of either stand-alone equipment or a component of a mining fleet management system such as that illustrated in Figure 9, some equipment can be partially automated to reduce the level of human involvement and/or expertise required to operate the equipment. The business case for partially automating equipment typically revolves around one or more of the following benefits:

- Repetitive Operations
If a component of the operating cycle of a piece of equipment is routine, standard and repetitive, a case often exists for automation underwritten by increased capital and operator productivity.

- **Requires skilled operator**
  Where the effective operation of a piece of equipment requires a skilled and relatively expensive operator and partial automation can reduce the skill level required to operate the equipment, a case for partial automation may be driven by increased labour productivity.

- **Occupational Health and Safety**
  Where part of the equipment’s operating cycle involves the manned equipment entering into an operating environment that proposes an OHS risk, a case may be made for automating that part of the equipment’s operating cycle so that operators aren’t exposed to a potentially dangerous environment. Similarly, a productivity case may revolve around facilitating equipment access to an environment that for OHS reasons would preclude an operator.

Examples of partly automated equipment include remote controlled boggers, self-aligning shears on long-wall miners and partly automated rock-bolters.

**Integration with Existing Datasets**

**Integration with Internal Datasets**

Most networked mining operations such as that depicted in Figure 9 above rely on internal datasets to inform decision-making, with external data linkages limited primarily to the supply chain such as equipment OEM’s and suppliers of equipment consumables. Internal datasets might include blast-block data, haul road condition data, maintenance scheduling, internal inventories of equipment consumables, equipment maintenance scheduling, human resources and training records, financial data systems and various internal reporting systems.

**Integration with External Datasets**

Some operations are benefiting from supplementing internal data sources with external data sources especially commercially available weather forecasting data and satellite imagery.

**Weather Forecasting Data**

Weather forecasting data is used to understand scheduling risk associated with operations that may be adversely or positively affected by weather conditions so that those tasks can, where possible, be scheduled at times when weather events are less likely to have a negative impact, or where weather events are likely to be favourable to a task. Weather data is also used for short-term forecasting so that immediate operations can be optimised for any unexpected weather events.

Commercial weather forecasting data is typically provided by public sector authorities responsible for meteorological forecasting such as the Bureau of Meteorology.

**Satellite Data**

As of year-end 2013, there were 1,167 satellites in operation, with more than 50 countries operating at least one satellite (some as part of a consortia). Figure 10 below summarises the distribution of satellites that are currently operational by function.
Revenues from the global satellite industry have grown from $144.4 billion in 2008 to US$195.2 billion in 2013\textsuperscript{35}. As illustrated in Figure 11 below, satellite services accounts for the majority of this revenue.

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\textbf{Figure 11 – Global Satellite Industry Revenues by Sector}

The satellite services sector is comprised of the following subsectors:

- **Consumer**
  The consumer subsector includes satellite television, radio and broadband.

\textsuperscript{35} Satellite Industry Association (2014), State of the industry Report
The fixed subsector includes transponder agreements and managed services. The mobile subsector includes voice and data mobile communications. The remote sensing subsector incorporates all remote sensing and imaging services.

The consumer subsector accounts for 83 percent of the $118.6 billion satellite services sector, with fixed and mobile accounting for an additional 14 percent and 2 percent respectively. While remote sensing only accounts for just over 1 percent of the satellite services sector’s revenue, revenue from remote sensing has grown from US$0.7 billion in 2008 to US$1.5 billion in 2013.

Approximately 80 percent of the commercial satellite imaging market is controlled by US government priority tasking. A total of nine commercial satellites currently send back high resolution imagery to the Earth. Historically, the United States Government has limited the resolution of imagery that can be sold commercially by United States companies to 50 centimetres. The United States Government recently amended this policy to allow image resolution of 25cm to be sold commercially. The number of high-resolution imagery satellites sending images to earth is expected to grow to 40 by the end of 2015 and 75 by the end of 2017.

The minerals industry has been a significant user of remote sensing data for exploration purposes for at least the past two decades. However, significant advances in the quality of remote sensing and satellite image data produced by both commercial and public sector satellites and new technologies for processing remote sensing data and satellite imagery is creating new applications for satellite data in the mining industry.

An example of this is the MineRECON® product developed by Sandpit Innovation. All mines undertake routine reconciliation of ore stockpiles. In the case of fast-moving bulk commodity mines such as the large iron ore mines of the Pilbara, the frequency of stockpile reconciliation can be monthly.

Ore stockpile reconciliations are performed by undertaking a volumetric estimate of the stockpile. Conventionally this is achieved by using ground-based quantity surveying instrumentation or by collecting and analysing airborne imagery collected by light aircraft or if the operating environment permits, unmanned aerial vehicles. This is a costly process with a slow turnaround time of approximately seven days.

Technology developed originally for military applications by Lockheed Martin has formed a platform that provides cost-effective rapid reconciliation of mining stockpiles from satellite data. The original technology was used to develop 3D models for defence mission rehearsal and urban planning applications. The technology platform uses stereo pairs taking two satellite photos one minute apart. Advanced processing techniques then process the image data to allow accurate and repeatable elevation values to be extracted and used in volumetric calculations.

In collaboration with Lockheed Martin, Sandpit Innovation have developed algorithms based on operational characteristics that are integrated into a stockpile reconciliation service that provides accurate and rapid stockpile volume reports customised to a client’s specific needs. Figure 12 below is an example of the stockpile imagery produced by MineRECON®.
New Equipment

There are many instances where new equipment has been developed to either generate data to support systems optimisation or to both generate data and perform an automated function based on the analysis of that data that replaces a previously unproductive function.

Equipment Developed for Data Generation Only

MillMapper

MillMapper is an asset monitoring and maintenance service that is based on a technology developed by Curtin University and the CRC for Spatial Science and commercialised initially by a company developed for that specific purpose, Scanalyse. Scanalyse was recently acquired by Outotec.

Most mining operations involve a crushing and milling circuit immediately upstream from the run-of-mine (ROM) stockpile. The purpose of this circuit is to reduce the ore to a particle size that is suitable for mineral recovery from downstream hydrometallurgical or pyrometallurgical processing techniques. Crushers are first used to break down relatively large rocks (>300mm) and mills are used to reduce the crushed ore to a particle size (typically <1mm) suitable for chemical liberation of the mineral.

The most commonly used mills are Autogenous (AG) and Semi-autogenous (SAG) ball mills which consist of large, rotating cylindrical vessels in which the ore is feed into at one end. Large steel balls mix with the ore in the rotating vessel whereby the ore is milled to a smaller particle size and fed out the other end of the rotating vessels through a discharge grate. Naturally, unless protected overtime the internal walls of the vessel wear through as a result of the friction of the balls and the ore. To mitigate this, the internal walls of the vessels are lined with sacrificial steel liners. As the steel liners wear they are replaced, protecting the shell of the vessel from wear.

The wear pattern of these liners is determined by the nature of the mill, how the mill is operated and the physical characteristics of the ore, all of which vary between mining operations and
over the life of a mining operation. If a liner wears through and the shell of the mill is damaged production is stopped and significant damage is caused to an expensive piece of equipment. This sort of failure is considered catastrophic.

The conventional method for mitigating this risk is that during a scheduled shutdown, an operator enters the mill vessel and using an ultrasound thickness gauge takes between 10 and 20 manual measurements of the internal surface of the liners. This process is time consuming, produces an incomplete dataset and presents OHS risk in that the operator is working in a hot confined space, the structures of which may have been damaged through operations. The time delay in accessing the mill can be up to three hours, as the ambient temperature inside the mill has to reduce to safe levels before the operator can enter.

MillMapper uses a conventional short-range terrestrial laser scanner which is remotely inserted into the interior of the mill vessel during a scheduled shutdown. The scanner automatically measures the liner thickness at millions of points within the vessel. Proprietary algorithms developed by Curtin University and the CRC for Spatial Sciences then produce a range of information including wear and wear rate of the liners, ball charge and liner volume, ball size and shape, grate-hole size and ball to ore ratio. This information is produced in both data and visual form. The entire process takes approximately 15 minutes as the laser can be deployed irrespective of the internal temperature of the mill vessel.

The data collected by the short-range laser scanner is processed and converted into a thickness model representing the liners, together with a range of other operational reports.

While MillMapper significantly mitigates the risk of catastrophic mill failure and improves the efficiency of the inspection process, significant amounts of data pertaining to the performance of the mill and its liners can be used by the liner manufacturers and mill operators to optimise the performance of the mill.

**Equipment Developed for Data Generation and Function**

**SPIDLER**

Conveyor belts used to transport ore in the mining industry transfer large tonnages, often over significant distances and challenging terrain at capacities in excess of 15 kilo-tonnes per hour (ktp/h). These conveyors are supported by idler rollers that are attached to the conveyor frames that run the length of the conveyor. Frames supporting smaller tonnage conveyors will typically have three rollers per frame, while larger tonnage conveyors will have five rollers per frame. The typical spacing of conveyor roller frames is every 1.0 to 1.4 metres along the entire length of the conveyor. Figure 13 below illustrates the frequency of the roller frames along an operational ore conveyor as well as different roller configurations to support different conveyor capacities.
Long ore conveyors are comprised of a large numbers of rollers. For example, the conveyor system at the Port Hedland bulk handling facility has approximately 120,000 rollers of which approximately 10,000 require replacement each year. Mining operation conveyors can also be required to navigate difficult topographies. For example, a conveyor system associated with a Vale operated mine in Brazil operates at 22 ktph on a 14 degree incline on a frame that supports it 40 metres above the surface.

The bearings in idler rollers periodically fail and if this occurs, a shutdown is required to replace the roller. In a typical bulk handling facility, a single roller replacement requires a shutdown period of approximately 1 hour. The current method for managing this event is that prior to scheduled shutdowns, a technician walks or drives alongside the length of the conveyor listening for ‘noisy’ rollers as an indication of pending bearing failure. ‘Noisy’ rollers are identified for replacement during the scheduled shutdown. Typically a team of unskilled labour is bought to site during the shutdown to replace the faulty rollers. This involves lifting the conveyor and man-handling the roller. Conveyor rollers on a 15 ktph conveyor weigh approximately 38 kilograms each, while rollers on a 22ktph conveyor weigh approximately 65 kilograms.

As a result of the weight of the rollers, the manual process and difficult working conditions (often including working at height), this process presents considerable OHS risk. Furthermore, a roller failure outside of a scheduled shutdown will result in at least an hour of lost production, which represents a significant cost to high throughput operations.

Sandpit Innovation has developed a device that can operate on a partly or fully automated basis that monitors and replaces faulty rollers outside of scheduled shutdowns without disrupting conveyor operation. This device, known as SPIDLER® is illustrated in Figure 14 below.
SPIDLER® operates on a light rail system that is installed along the length of the conveyor. At periodic intervals (typically in the range of one to seven days) the SPIDLER® device moves along the length of the conveyor to detect failed bearings or bearings that are approaching failure. A thermal imaging camera that is mounted on the SPIDLER® device detects roller bearing and shell temperature changes between each scan. Software monitors the temperature over a threshold and the change in temperature between scans to assess bearing and shell condition. Optimally, the scanning operations are conducted at night when there is less background and reflective heat.

SPIDLER® then produces a report on the condition of the rollers based on an analysis of the scan data, identifying failed rollers and rollers that are approaching failure. This report is then assessed by an operator who can make a decision as to rollers that require replacing. While algorithms have been developed that allow SPIDLER® to make this decision, adoption risk is being managed by incorporating human judgement in the process. Once the operator has decided which rollers require replacement, the SPIDLER® device is programmed with a replacement mission.

Once programmed, the SPIDLER® devices loads itself from an off-board roller storage magazine and moves along the conveyor to the frame where a roller requires replacement. At this point mechanical arms with rollers raisers engage under the conveyor belt and slowly lift the belt up by approximately 200 millimetres at the same trough angle at which it is operating, allowing the conveyor to continue to operate. A robotic arm coupled to a tooling assembly then removes the faulty roller and replaces it with a new roller from the on-board roller nest. Once the faulty roller has been replaced, the conveyor belt is lowered back into position and the SPIDLER® moves along the conveyor to the next roller replacement job.

The main capital investment associated with installing the SPIDLER® is the installation of the light rail system which mounts to the existing conveyor frame alongs the length of the
conveyor. The light gauge rail is central to the SPIDLER®’s unique design. It provides the means for further automation and allows the machine to service the conveyor regardless of surrounding terrain or inclines. However, even with the requirement for this infrastructure, modelling on the payback suggests that the system can return value within a year.

While the avoidance of a critical failure outside of scheduled shutdowns and reduced OHS risk are obvious benefits associated with SPIDLER®, it is the ability to completely change the way both unplanned and planned roller change outs are performed that delivers the greatest value. On board condition scanning and data can be used by asset management systems to optimise the performance of the conveyor, spare parts inventories and maintenance scheduling. Shifting the process of changing conveyor rollers from a very reactive bases to a ‘on condition’ approach.

Observations

In its analysis of adoption of automation, the Rise of the Machines? study refers to the characteristics of an innovation that are most critical in driving the rate and extent of the adoption of an innovation in any industry, namely relative advantage, compatibility, complexity, trialability and observability36. These drivers of the rate and extent of adoption of an innovation are summarised in Appendix 3.

To varying degrees each of the examples of component automation discussed in the previous subsections present elements of relative advantage, compatibility, complexity, trialability and observability that are prima facie conducive to adoption:

- **Relative Advantage**
  All of the examples discussed in the previous subsections deliver clear benefits over the alternative method of addressing the operational issue.

- **Compatibility**
  With the exception of perhaps SPIDLER ® that requires the installation of a light rail system alongside the conveyor, and to some extent fleet management systems which may require additional site networking infrastructure, each of the innovations can be implemented with very limited change to the way the operation is currently managed.

- **Complexity**
  Each of the innovations described is relatively easy to understand and use.

- **Trialibility**
  Each of the innovations can be implemented whilst still using the current approach to managing the operational issue and/or on part of the operation only, thus allowing the operation to manage operational risk.

- **Observability**
  The benefits delivered by the innovation discussed in the previous section are observable in a short period of time and clearly attributable to the innovation.

Anecdotally, there is also a relationship between the level of adoption of different types of component automation and the maturity of the use of the technology platform in other industries. For example, vehicle management system are becoming relatively commonplace in mining fleets, but have been ubiquitous in fleet management in other industries for many years. The relationship between adoption of different types of component automation and

the maturity of the technology platform in other industries is illustrated conceptually in Figure 15 below.

![Diagram showing relative maturing of technology platform in other industries and relative level of adoption in the Australian mining industry.]

**Figure 15 – Extent of Adoption of Different Types of Component Automation**

For rational economic reasons discussed in detail in *Rise of the Machines?*, the mining industry is a relatively late adopter of innovation in most cases. The observation above suggests that even in the case of component automation, where adoption is occurring more readily, much of the Australian resources industry remains a conservative adopter of new technologies compared to many other sectors of the economy.

The implication of this is that in most cases, the key technical skills that are required to deploy and manage the technology platforms that underpin component automation in the mining industry are already exist in the wider technical services market, including the mining services sector and to varying degrees are developed within the trades and professions that support these innovations, as well as the training and education programs that deliver that produce trade and professional qualified technical staff.

However, an area in which the resources industry is increasingly likely to face skills shortages is in optimising opportunities that arise from the extensive operational data that will be produced.
from increased component automation, as well as managing that data. This is discussed in the next section of the report.
Component Automation in the Australian Resources Industry and a Big Data Operating Environment

The volume of data produced by ICT systems worldwide is estimated to be growing at approximately 40 percent per annum and will increase by 44 times between 2009 and 2020\(^\text{37}\). It has been estimated that the digital universe currently includes 2.7 zettabytes (a zettabyte is approximately equivalent to 1.1 trillion gigabytes) of data\(^\text{38}\).

Generally speaking, the uptake and effective use of ICT services in most organisations, in most sectors can facilitate a range of innovations, including technological solutions that enable efficient and streamlined business processes, advanced technological tools that open up new models of production and new market sectors, and new ways to maximise staff productivity through mobile telephony and teleworking\(^\text{39}\).

A recent survey of approximately 300 IT decision-makers for a range of industries found that:

- 62 percent of respondents currently store at least 100 terabytes of data;
- 32 percent expect the amount of data they store to double in the next two to three years;
- 62 percent of respondents want to develop near-real-time predictive analytics or data mining capabilities in the next 24 months;
- 58 percent of respondents plan to expand data storage infrastructure and resources;
- 53 percent of respondents hope to analyse increasing amounts of unstructured data\(^\text{40}\).

As illustrated by the case study below, large volumes of diverse operational data have played an important role in optimising operations in the resources industry for some time. Operators of large complex minerals processes have long used a range of sensor produced data as inputs to simulation models designed to optimise processes. More recently, the iron ore industry has been using data generated across its operations to optimise operations from ‘blasting-to-port’.

The proliferation of component automation throughout the spectrum of minerals operations, will continue to drive a shift from conventional mine operations management to a form that is more data intensive.

It has been estimated that approximately 1.5 percent of a new resources project spend is on ICT infrastructure\(^\text{41}\). Based on projects that proceeded to a committed stage between 2003 and 2012, this equates to a total ICT spend of approximately $6.0 billion in the Australian resources industry\(^\text{42}\), not including ICT investment in existing operations.

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\(^{39}\) Australian Workforce and Productivity Agency (2013), *ICT Workforce Study*, Australian Government, Canberra
\(^{40}\) Microsoft (2012), *Global Enterprise Big Data Trends*
\(^{41}\) AustAsia Mintech (2014) [www.ausasia-mintech.com.au]
\(^{42}\) AustAsia Mintech (2014) [www.ausasia-mintech.com.au]
Big Data: An Overview

The term ‘Big Data’ refers to datasets the size of which is beyond the ability of typical database software tools to capture, store, manage and analyse. The definition is intentionally subjective, designed to take into consideration the fact that Big Data is contextual. Variability in datasets, different database and analytical software used by different sectors, different storage capability available to different operations and sectors and the ongoing advancement of technology means that Big Data has to be defined in the context in which it exists and is being used.

Big Data is typically produced from the following sources:

- **Traditional Enterprise Data**
  This includes customer information from CRM systems, transactional ERP data, web store transactions and general ledger data.

- **Machine-Generated and Sensor Data**
  This includes Call Detail Records (CDR), weblogs, smart meters, manufacturing sensors, equipment logs (sometimes referred to as digital exhaust) and trading systems data.

- **Social Data**
  This includes customer feedback streams, micro-blogging sites like Twitter and social media platforms like Facebook.

In 2013, the Big Data industry turned-over US$18.6 billion, representing a 58 percent growth rate over 2012. The industry is expected to achieve sales of US$50 billion by 2017, with 40 percent of this revenue generated from related services, 38 percent from hardware and 22 percent from software. Table 5 below summarises the main drivers and constraints to the expansion of the Big Data industry.

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Constraints</th>
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<tbody>
<tr>
<td>Growing confidence in Big Data products and services among enterprise purchasers as a result of improved communications from the vendors</td>
<td>A lack of best practices for integrating Big Data analytics into existing business processes</td>
</tr>
<tr>
<td>Growing maturity of those Big Data products and services, including the release of YARN</td>
<td>Concerns over security and data privacy</td>
</tr>
<tr>
<td>The addition of better privacy, security and governance capabilities in those products as well as improved backup and recovery and high availability for Hadoop specifically</td>
<td>Continued ‘Big Data Washing’ by legacy IT vendors</td>
</tr>
<tr>
<td>The growing number of partnerships, particularly reseller agreements and technical partnerships between Big Data and non-Big Data vendors</td>
<td>A volatile and fast developing market</td>
</tr>
<tr>
<td></td>
<td>Lack of polished Big Data applications for solving specific business problems</td>
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</tbody>
</table>

**Table 5 – Big Data Industry: Drivers and Constraints**

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Business Value of Big Data

There are five broad ways in which businesses can leverage Big Data into transformational value creation⁴⁵:

- **Creating Transparency**
  Significant value can be created within organisations simply by making more data easily accessible to relevant stakeholders in a timely manner. For example, integrating data from exploration and mining with the processing plant can enable processing plant optimisation that reduces input costs and increases recovery.

- **Enabling Experimentation to Discover Needs, Expose Variability and Improve Performance**
  Significant longitudinal data sets across a wide-range of operating variables enable organisations to develop models to analyse variability in performance, to understand the root cause of that variability and put in place management and systems measures to optimise performance.

- **Segmenting Population to Customise Actions**
  Big data facilitates the creation of highly specific segmentations that can be used to tailor products, services and operational actions to meet the specific requirements of those segments, thus optimising performance and value propositions. This segmentation has applications in marketing, risk management and operational control.

- **Replacing/Supporting Human Decision Making with Automated Algorithms**
  Sophisticated analytics can substantially improve decision-making, minimising risks and identifying valuable insights to support decisions that would otherwise not be visible. In some instances Big Data analytics will allow full automation of decisions, in other instances it will inform human judgement, resulting in better decisions.

- **Innovating New Business Models, Products and Services**
  Big Data allows companies to create new products and services, enhance existing products and serves and develop entirely new business models.

Operational Challenges Associated with Big Data

Big Datasets include structured and unstructured data. The challenges associated with extracting value from Big Data are summarised in Table 6⁴⁶ below.

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<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>A number of factors have increased data volume including transaction based data stored over time; unstructured data streaming from social media; and sensor and machine-to-machine data. Historical challenges associated with storing large amounts of data have been addressed from both a technological and economic perspective. For example, a single get engine can produce 10 TB of data in 30 minutes, which equates to multiple Petabytes of jet engine data being able to be produced from the airline industry daily.</td>
<td>Determining the relevance of large data volumes and designing analytics to create value from those large volumes of data.</td>
</tr>
<tr>
<td>Velocity</td>
<td>Data streaming operates at unprecedented speed. Technologies such as RFID tags, various sensors and smart metering are producing enormous amounts of real-time and near real-time data. For example, at 140 characters per tweet, the high frequency of tweeting produces over 8 TB of data per day.</td>
<td>Developing systems that can react quickly enough to get practical results from the data.</td>
</tr>
<tr>
<td>Variety</td>
<td>Data is produced in a wide range of formats including structured, numeric data; information created from line-of-business applications; unstructured text documents; email; video; and audio.</td>
<td>Developing systems that can not react quickly enough, but integrate and analyse different types of data to get practical results from the data.</td>
</tr>
<tr>
<td>Variability</td>
<td>In addition to increasing velocities and varieties of data, data flows are often highly inconsistent with periodic peaks.</td>
<td>Ensuring processing systems have capacity at the times when capacity is required and predicting those times.</td>
</tr>
<tr>
<td>Complexity</td>
<td>Data is produced from many different sources.</td>
<td>Linking, matching, cleaning and transforming data across systems is challenging requiring the development connect and correlate relationships and hierarchies for multiple data linkages.</td>
</tr>
</tbody>
</table>

**Table 6 - Dimensions of the Challenges Associated with Big Data**
Case Study - Alcoa Western Australian Bauxite Library

Alcoa operates refineries in the United States, Brazil, Jamaica, Spain, Suriname, and Australia, providing it with a global refining capacity of approximately 14 million tonnes per annum, or approximately one third of global supply.

Each year Alcoa drills between 60,000 and 70,000 resource development holes and takes 10 samples per hole for assaying across its operations in Western Australia. The robotically controlled assay laboratory automatically performs Fourier Transform Infrared Spectroscopy (FTIR) analysis on up to 700,000 samples per annum, an average of approximately 2,000 assays per day. This has resulted in an enormous ore characterisation database.

Alumina is recovered from bauxite ore using a very complex process known as the Bayer Process. Controlling production in an alumina refinery is a complex task requiring the processing of large volumes of bauxite, caustic soda, lime and other raw materials by large plants to digest the alumina minerals from the bauxite, separate the remaining waste material, re-crystallise and then calcine the hydrate to produce the alumina product. Despite the process being highly automated, there is still need for significant human operation. For example, there are 10,000 valves at the Wagerup refinery that require manual operation.

Alcoa’s refineries are characterised by an enormous number of sensors that monitor plant performance at every stage. This data is integrated with the ore characterisation database and expertise from practitioners to optimise plant performance. Regardless of the significant ore and plant database, as well as the long operating history, the Alcoa plants still experience unexplained phenomenon.

As a result of the complexity of this process, as well as additional complexity caused by variability in the composition of the bauxite feedstock and recycling of reagents used in the process, developing accurate algorithms that facilitate monitoring, simulation and control is particularly challenging. This challenge is exacerbated when it needs to be implemented across seven different sites globally, exhibiting different organisational cultures, national cultures and multiple languages.

In collaboration with Honeywell, Alcoa developed its Quality Automation Solutions in Alumina Refining (QUASAR) system. At a cost of approximately $0.5 billion, this system facilitates the monitoring and control of seven refineries across four continents from a single operations centre in Perth. This is a complex system running approximately 50,000 simultaneous algorithms.

The scope of developing and implementing such a system is significant:

- Standardisation of infrastructure across operations
- Integration of process control ITC so that all refineries are interconnected
- Standardisation of deployment of instrumentation across all refineries
- Development of advanced control and automated control based on prediction of the process and optimisation of algorithms

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• Applications that integrate, optimise and coordinate activity of the processing unit (upstream and downstream)

The main driver for QUASAR is that in some countries and in remote locations it is difficult to deploy the expertise necessary to operate the facilities. The global control centre is located in Perth for two reasons:

• **Significant refining capacity in Perth**
  Alcoa’s operations in the south west of Western Australia produce approximately 15 percent of the world’s alumina.

• **Location of the global Technology Delivery Group (TDG)**
  Alcoa’s Technology Delivery Group is based at the Company’s Kwinana Refinery and is comprises approximately 80 chemists, other scientists, engineers and mathematicians overseeing a research and development budget of approximately $25 million per annum. A main focus of this group has been the development of instrumentation to monitor all aspects of the plant’s performance.

QUASAR makes an enormous volume and variety of data available. Expertise is required to ask the right questions and select the data that can best help answer those questions. This is a key challenge in a Big Data operating environment.

**Big Data in the Resources Industry**

Much of the contemporary analysis on the potential impact of Big Data and supporting ICT systems on sector performance focuses on sectors for which data management is customarily core business such as the finance and insurance, computer and electronic products, wholesale trade, government and information sectors. Nevertheless, the Australian resources industry is positioning to derive significant benefit from the deployment of component automation, the ICT systems that support that component automation and the resulting Big Data operating environment.

Much of the data produced by resources operations with a high intensity of component automation is machine-generated data, which is produced in much larger volumes than most other sources of Big Data. In the case of resources operations, this data is also characterised by significant variety, velocity and variability and includes:

• Geological and geospatial data
• Maintenance and asset information
• Process control and automation data
• Environmental data
• Production data
• Financial data
• Supply chain data

Almost all sectors of the economy stand to benefit from Big Data. However, by virtue of the value and quantum of data produced, some sectors of the economy stand to reap greater

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50 Deloitte (2012), Digital Disruption – Short Fuse, Big Bang? Building the Lucky Country: Business Imperatives for a Prosperous Australia series, No. 2,

51 IBISWorld (2012), A Snapshot of Australia’s Digital Future to 2050
benefits from Big Data than others. McKinsey categorise sectors with respect to the impact of Big Data across five broad categories. These are summarised in Table 7 below⁵².

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Sectors</th>
<th>Big Data Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Computer and electronic products Information</td>
<td>Already experiencing very strong productivity growth and well positioned to gain substantially from Big Data</td>
</tr>
<tr>
<td>B</td>
<td>Finance and insurance Government</td>
<td>Positioned to benefit very strongly from Big Data as long as barriers to its use can be overcome</td>
</tr>
<tr>
<td>C</td>
<td>Arts and entertainment Management of companies Educational services Construction Other services</td>
<td>Sectors that have experienced negative productivity growth, indicative of strong systemic barriers to increasingly productivity</td>
</tr>
<tr>
<td>D</td>
<td>Administrative support and waste management Manufacturing Transportation and warehousing Professional services Wholesale trade</td>
<td>Globally traded sectors with high historical productivity growth</td>
</tr>
<tr>
<td>E</td>
<td>Utilities Retail trade Accommodation and feed Real estate and rental Healthcare Natural resources</td>
<td>Local services that have experienced lower productivity growth.</td>
</tr>
</tbody>
</table>

**Table 7 - Expected Sectorial Benefits from Big Data**

According to this analysis, opportunities derived from Big Data are less for natural resources than many other sectors. However, it needs to be noted that in this analysis, the natural resources sector includes agriculture, forestry, fisheries and other natural resources subsectors. In many of these subsectors the immediate availability of big data, as well as opportunities for

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significant improvements in performance based on Big Data applications is likely to be less than for the minerals and oil and gas subsectors.

In addition to how much benefit can be gained from Big Data, McKinsey also undertook an assessment of how well positioned a sector is with respect to capitalising on the availability of Big Data. This can be examined as a function of management talent with respect to managing Big Data, IT intensity of the sector, degree to which there is a data-driven mindset and the availability of data. Under this analysis, the resources sector performs relatively well, with the exception of ICT intensity (which is rapidly improving with the event of component automation) and internal big data capability. This is summarised in Table 8 below.

<table>
<thead>
<tr>
<th>Big Data Management Capability</th>
<th>Performance Relative to Other Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data driven mindset</td>
<td>First quintile</td>
</tr>
<tr>
<td>Data availability</td>
<td>First quintile</td>
</tr>
<tr>
<td>Overall ease of data capture</td>
<td>Second quintile</td>
</tr>
<tr>
<td>IT intensity</td>
<td>Third quintile</td>
</tr>
<tr>
<td>ICT and analytical talent</td>
<td>Fifth quintile</td>
</tr>
</tbody>
</table>

**Table 8 – Resources Sector Big Data Management Capability Relative Performance**

A significant constraint on realising value from Big Data across industry will be a shortage of talent, particularly of staff with deep expertise in statistics and machine learning, as well as the managers and analysts who understand how to design and implement organisational management decisions using insights from Big Data. The resources industry will compete with other industries for this talent. This is discussed further in a subsequent section of this report.

A survey of resources company executives undertaken by Business Spectator in conjunction with IBM in late 2012 found that:

- 52.5 percent of respondents admitted that they did not yet have a strong capability in data analytics;
- 47.5 percent of respondents stated that only one or two executives in their organisations are involved in the decision making process pertaining to the use of analytics in their organisations;
- 55 percent of respondents had involvement with Big Data in their organisations; and
- Only 20 percent of respondents said that Big Data analytics were high or very high on their company’s investment agenda.

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55 Business Spectator and IBM (2012). *Big Data: Mining and Natural Resources*
Implications for Workforce, Skills, Training and Education

Workforce Structure

Workforce development involves more than simply formal learning undertaken by individuals in secondary and tertiary education. Skill and capability development is an ongoing responsibility that requires employees, employers and education and training providers to work together to ensure that organisations can develop, attract and retain the skills required to drive productivity and that individuals can acquire the skills that are necessary for them to do their jobs effectively\(^{56}\). The event of component automation in the Australian resources industry is a contemporary case study of this dynamic in action.

Consistent with the findings of the *Rise of the Machines?* study, the increased incidence of component automation will introduce new technologies to the resources industry, for which particularly the traditional mining industry workforce skill profile, would arguably not be able to support. Similarly the increasing incidence of component automation will require modification to work patterns and operational culture. However, companies, the workforce and the training and education sector seems to be adequately adapting to this challenge. This is because in the case of most component automation, the platform technologies that underpin component automation in the mining industry are relatively well established in other industries.

As with most automation, the event of component automation may result in some roles becoming redundant. However, in many instances it will drive a restructuring of roles. For example, component automation that results in a piece of equipment being able to be controlled by a less skilled operator (e.g. remote controlled bogger) may render a skilled operator redundant from that role. However, it is very likely that the skilled operator will be absorbed into a business process analytical role where their deep operating knowledge can be applied to operational data produced by the new partially automated equipment and other sources to optimise relevant processes.

According to a study undertaken by the Australian Workforce and Productivity Agency\(^ {57}\), when compared to other sectors of the Australian economy, the mining industry employs relatively few ICT managers, ICT professionals and ICT technicians and trade persons. This is likely to change over the short term as operations build their ICT capacity to support component automation.

*Rise of the Machines?* identified the following three new key roles that would become more prevalent as automated systems continue to be adopted by the resources industry:

- Automation Technician
- Mechatronics Engineer
- Production Manager and Process Optimisation Experts

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\(^{57}\) Australian Productivity Workforce and Productivity Agency (2013), *ICT Workforce Study*, Australian Government
These roles will continue to be increasingly required by a resources industry characterised by a higher level of component automation. In fact, it is likely that the fact with component automation potentially being a more attractive investment proposition to more resources operations, demand for these skill sets will likely grow quite rapidly.

**Trades**

The number of tradespeople employed onsite is unlikely to be dramatically affected by increased incidence of component automation because:

- Existing equipment that has been partly automated will still require most of the same routine maintenance;
- It is likely that in many operations additional equipment will be introduced to generate data or generate data and perform an automated function; and
- Higher throughput and capital utilisation that will result from component automation will potentially create more frequent maintenance scheduling for some equipment in some operations.

There is also likely to be a greater requirement for electrical trades, networking technicians and automation technicians to support the ICT aspects of the equipment that gives effect to component automation as well as to progressively network the entire operation. The skills that are likely to be increasingly required from an automation technician on a resources project are summarised in Table 9 below.

<table>
<thead>
<tr>
<th>Control Technologies</th>
<th>Communication and Computer Technologies</th>
<th>Electrical Installation and Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLC programming</td>
<td>Computer configuration</td>
<td>Equipment selection</td>
</tr>
<tr>
<td>Embedded PC programming</td>
<td>Fieldbus technology</td>
<td>Systems verification</td>
</tr>
<tr>
<td>Control parameters selection</td>
<td>Computer networking principles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wireless digital communication</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operating system types</td>
<td></td>
</tr>
</tbody>
</table>

**Table 9 – Skills that will be Increasingly Required by Resources Industry Automation Technicians**

**Mechatronics Engineer**

Mechatronics engineering is a multidisciplinary field that combines electrical, mechanical, computing and software engineering to create expertise in designing, building, deploying and maintaining electromechanical devices such as robots. While this skill set is highly relevant to component automation, operators are reporting that electrical engineering graduates are familiar with most of the new technologies being deployed at mining operations and very quickly able to work with them.

A particular skills set that is common to mechatronics engineers that is very relevant to component automation is data fusion expertise. As discussed in an earlier section of this report, the absence of integration standards will result in a need to write software code that integrates component automation with the operation’s overall ITC system and other pieces of component automation. This expertise also typically resides with computer programmers and systems analysts.

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58 Adapted from: Mining Industry Skills Centre, Automation Skills Strategy
Production Managers and Process Optimisers

As component automation proliferates and large amounts of operational data becomes increasingly available from all aspects of the mining operation, opportunities to apply professional process and logistics optimisation skills to optimising the productivity of the overall operation will arise.

Big Data Analyst

In addition to the three new emerging roles identified by the Rise of the Machines? study, this study has identified an additional role that will become increasingly important as component automation becomes more commonplace in mining operations. As component automation is increasingly adopted, resources operations will enter into a Big Data operating environment.

The ability to harness, analyse, plan and act on Big Data presents resources companies with enormous opportunity to increase productivity and reduce costs. The key challenges to creating competitive advantage through the management of Big Data in a resources company include:

- Determining what data should be collected and analysed in order to make informed operational and business decisions that have a positive impact on key resources business issues such as productivity and OHS
- The vast majority of organisations operating in the resources industry operate numerous legacy systems. Consolidating data platforms and overcoming legacy systems issues is a major organisational and technical challenge
- Resources projects and operations are characterised by many different stakeholders including the actual operating company, major contractors, EPCMs and various OEMs and suppliers. Each of these stakeholders produces data through their activities and wants access to other data to enhance the productivity and outcomes of their activities. Determining priorities and commercial issues, including the nature of data ownership, around who has access to what data is a key business issue
- Organisational issues around breaking down silos applicable to functional needs so that wider commercial and operational decisions can be enhanced
- Ensuring data is used properly and interpreted appropriately.

A significant constraint on realising value from Big Data across industry will be a shortage of talent, particularly of staff with deep expertise in statistics, pure mathematics, computational chemistry, machine learning, as well as the managers and analysts who understand how to design and implement organisational management decisions using insights from Big Data.59 Again, Australia’s poor performance in STEM education does not fare well for this requirement.

Remote Operations Centres have been established in Western Australia by a range of resources companies, including Alcoa, Rio Tinto Iron Ore, and BHP Billiton Iron ore, Fortescue Metals Group, Roy Hill and Woodside. Reliable access to Big Data analytical skills will become important to Western Australia if it is to build on its current growth in operations centres.

Implications for Vocational Education and Training

Resource project operators are reporting that new apprentices are entering the workforce with:

- At least a familiarity with the new technologies being deployed on resources projects;
- Reasonably well developed understanding of base level mathematics, science and engineering concepts;
- Problem-solving mindsets.

It has been observed by resources project operators that this has resulted in a generation of tradespeople who are able to quickly develop skills either on-the-job and/or through OEM training to support incremental new technologies that emerge in their field of expertise.

The fact that the current generation of new tradespersons is more adaptable to new technologies is likely the result of:

- Higher resources sector remuneration of more recent times attracting higher acumen individuals into trades than has perhaps previously been the case;
- Generally higher lifetime technology exposure (including frequency of introduction of new technologies) and proficiency possessed by Generations Y and Z; and
- The introduction of relevant technologies to the structured learning component of trade certificate programs.

The increasing requirement for networking and automation technician roles will likely be met by evolving certificate level curriculum, new diploma level qualifications and post-trade programs offered by mining equipment OEMs.

Implications for Higher Education

It is likely that undergraduate and graduate electronic and mechatronic engineering programs will continue to meet the professional technical skill needs of a mining industry that is characterised by a higher incidence of component automation.

However, while engineering faculties may produce some of the skills relevant to Big Data analytics, skills such as statistics, pure mathematics, computational chemistry and machine learning may come from graduates from mathematics and science programs.

It is the market for these roles in which the resources industry may face the biggest challenge. As discussed in a previous section of this report, it is in the area of ICT and data analytical talent where the resources industries perform relatively poorly compared to other sectors. It is also this area where competition for skills is likely to be significant from other sectors.

The relatively poor trend in STEM education in Australia doesn’t present a positive case for increasing numbers of graduates from Australian universities that can meet this demand. However, the trend in STEM education in many Asian nations\(^6\), suggests that Asia may be a source of supply for this emerging skills requirement. It should be noted that because data is mobile, it is possible that some Big Data analytical tasks may not require the data analyst to be in-situ. As such, it may eventuate that in the case of Australia some Big Data services are imported.

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Skills Relationships with Other Industries

With respect to technology, the industries with which the resources industry arguably has the closest technology sourcing relationship with is the defence industry, which is not surprising given the commonality in field deployment conditions, requirement for high levels of systems reliability and high OHS standards. The resources industry also has a technology sourcing relationship with the automotive industry that stems from the intensive deployment of wheeled vehicles in most mining operations.

Competition for Talent with the Defence Industry and Prospects for Talent Collaboration

Significant technological advances with defence applications are likely to occur in many of the technical fields that are relevant to automation in the resources sector including unmanned operation, materials, nanotechnology, computing, integration and control of electronic warfare capabilities and sensing and simulation.

The importance of unmanned air, maritime and land platforms are proliferating not only among national defence forces around the world. Semi-autonomous unmanned systems able to engage in both self-protection and offensive action are under development internationally. Although there are significant challenges in making these systems operationally useful, it is possible that they will be deployed by defence forces in the mid-2020s. The increased use of unmanned platforms across a range of sectors will create competition for the skills required to support them.

The technology sourcing relationship between the defence force and defence industries and the resources industry is highly complementary, with the resources industry providing a market for many mature defence technologies once their strategic sensitivity is diminished. However, this technology relationship also results in competition for technical skills. Defence force technicians and tradespersons not only have skills relevant to the type of technology that is typically deployed in the resources industry, but also usually possess a work ethic and OHS culture that is desirable to the industry and are typically comfortable working in remote locations for periods of time. Strong resources sector competition for skilled employees has been highlighted by the Australian Defence Force.

Australian Defence Force Employment Dynamics

The Australian Defence Force as an Employer of Technical Expertise

The Australian Defence Force (ADF) is a major employer of a skilled workforce and a significant contributor to the education, training and development of the broader Australian workforce. It employs approximately 57,000 permanent ADF personnel, 26,000 reservists, 23,304 APS staff and 500 contractors. Almost 50 percent of ADF personnel are employed in technical roles.

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61 Australian Defence Force Posture Review: Initial Assessment Against the Review’s Terms of Reference (Attachment C)
Approximately 40 percent of Navy, 15 percent of Army and 50 percent of Air Force non-officer workforce are employed in technical trade positions.  

Training at the Australian Defence Force

Because of the very specific technical nature of many job roles at the ADF, the ADF conducts the majority of training of its members internally, with initial training for new members ranging in duration from only a few months to many years. There is limited opportunity for lateral recruitment into the ADF or for the ADF to benefit from sources of workforce supply such as skilled migration.

Approximately 90 percent of technical trade jobs within the ADF do not require previous experience. There are thirty different trade jobs across all three services grouped according to the following five broad categories:

- Aviation
- Construction
- Electro-technology
- Engineering
- Automotive

The ADF operates four Registered Training Organisations (RTOs) which deliver training and assessment for 24 training programs. The ADF also procures and delivers a number of higher education programs, typically in partnership with Australian universities.

Training in the ADF is principally linked to work function, which in turn increases job satisfaction, as well as retention. Defence acknowledges that many of the skills required by personnel during their ADF career will ultimately assist personnel transitioning to employment outside of the ADF. To reduce the risk of personnel making this transitioning early in their career, the ADF has sought to provide training to the level required at particular points in their career rather than frontloading to meet a particular VET qualification. This is also required because the ADF is a relatively rapid adopter of new technologies, strategies resulting in relatively frequent changes to training program curriculum.

As such, the lead time to develop military skills, especially in highly complex categories is significant.

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In order to further linkages with industry, particularly the defence industry, and provide skilling opportunities, ADF supports a number of industry placement programs, particularly in technical related areas.

**Maintaining Critical Mass is a Major Challenge**

Almost all Defence personnel are recruited at base ranks (and generally early in their working life) and then progress through the workforce system, gaining skills, experience and promotion.

Maintaining a critical mass of personnel is a major ongoing challenge for the Australian Defence Force (ADF), with the ADF required to recruit more than 4,900 ab initio personnel each year in order to retain its strength.

The highest separation points for ADF personnel are the first year and the year corresponding to the completion of the first term. First-year separations accounts for approximately 17 percent of annual separations from personnel other than officers and are most commonly associated with training separations.

A study undertaken in 2012 examining variables associated with failure to complete Initial Minimum Period of Service for recruits between July 2002 and July 2010 found that among other things, recruits to the ADF that undertook technical occupations across all of the services were more likely to complete their first term. This is illustrated in Figure 16 below.

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**Figure 16 – Portion of ADF Recruits Completing First Term by Occupation Type**

As illustrated in Figure 17 below, first term completion rates in trades that are particularly relevant to resources industry automation (communications, intelligence and surveillance, logistics and administration and engineering, construction and maintenance) averages approximately 72 percent.

![Percentage of Recruits Completing First Term by Occupation Type](image)

**Figure 17 – Portion ADF Recruits Completing First Term by Occupation**

**Defence Industries**

Over the next decade, the Australian Government is planning a substantial increase in Defence acquisitions across all services, at an estimated cost of more than $200 billion\(^1\).

The Defence Materiel Organisation (DMO) estimates that over the next 10 years, approximately 53 percent of its total acquisition and sustainment investment will be spent in-country. Over the same period, an estimated 37 percent of capital equipment acquisition and sustainment will be spent on domestic activity, while approximately 70 percent of the Australian Defence Force (ADF) sustainment expenditure will be spent in Australia\(^2\).

Defence projects are typically complex, characterised by long lead times and frequent disruption to scheduling. They are also interrupted by changes in government policy and defence budget. A critical factor for developing and maintaining a skilled Defence industry workforce is maintaining a constant flow of project work to industry.

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\(^1\) Skills Australia (2012), *Defence Industry Workforce Strategy: Background Paper*, Australian Government

Defence related industries include shipbuilding and repair, boatbuilding and repair, aircraft manufacturing and repair, fabricated metal product, explosive manufacturing and air space transport.

The defence industry is a relatively small employer in the context of the Australian workforce. It is estimated that approximately 15,000 to 25,000 persons are employed by firms in the defence industry whose current work relates to expenditure by the DMO at any given time. Given that many of the firms working in the defence industry also undertake significant civilian work contracts, many employees engaged directly or indirectly in supporting the ADF’s material requirements could move between military and civilian tasks if required.

As a result of significant escalation in contracting out many aspects of the provision of military equipment and sustainment to the defence industry over the past two decades, the ADF and the defence industries are highly integrated entities.

Indeed the ADF periodically develops and publishes Priority Industry Capabilities (PICs). PICs identify elements of broader industry capabilities that confer an essential strategic advantage by being resident in Australia and which, if not available, would undermine defence self-reliance and ADF operational capability. The current PICs are as follows:

- Acoustic technologies and systems
- Combat clothing and personal equipment
- Electronic warfare
- ‘High-end’ system and ‘system-of-systems’ integration
- High frequency and phased array radars
- Infantry weapons and remote weapon stations
- In-service support of the Collins Class submarine combat system
- Selected ballistic munitions and explosives
- Ship Dry-docking and Common User facilities
- Signature management
- Through-life and real-time support of mission critical and safety critical software

Across the defence industry, the greatest demand for skills relates to highly technical occupations in the engineering professions and trades. The ten most important professional and trade occupations to sustaining Defence related industries are summarised in Table 10 below.

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73 Skills Australia (2012), Building Australia’s Defence Supply Capabilities: Main Report for the Defence Industry Workforce Strategy, Australian Government, Canberra
74 Australian Industry Group Defence Council (2013), Why We Need a More Focussed Defence Industry Policy, Submission by the Australian Industry Group Defence Council to the 2013 Defence White Paper Process
Since 2005, the DMO has run a program designed to grow the skills base of the defence industry, create pathways into the sector and address identified skills capability gap. The program, known as Skilling Australia’s Defence Industry (SADI) is designed to provide funding to Australian companies or defence industry associations with a current Defence contract or who are expecting to tender for a defence contract within the next 12 months with funding for staff training. The proposed training program must be targeted at an identified shortage in trade, technical or professional skill sets and must be of strategic benefit to the ADF. Eligible training activities include technical and trade courses and workshops and professional courses in engineering, logistics, project management and scheduling. Typically training that is supporting the PICs will be given priority.76

Many of the capabilities that are required in the defence industry such as systems-of-systems integration, test and evaluation, modelling and simulation, qualification and certification; and manufacturing technologies77 are similar to those required in an increasingly automated resources industry.

As component automation continues to penetrate resources industry operations an opportunity exists to better integrate technology transfer, technical training and post-service employment arrangements between the ADF, defence industries and the resources industries to the mutual benefit of the three sectors.

**Implications of the Demise of Australia’s Automotive Manufacturing Industry**

The automotive industry is a major driver of technological advancement and skills development in many countries. As a result of the complex nature of the industry, automotive industry employees develop valuable skills covering R&D, design, sourcing, manufacturing,

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77 Australian Industry Group Defence Council [2013], Why We Need a More Focussed Defence Industry Policy, Submission by the Australian Industry Group Defence Council to the 2013 Defence White Paper Process
supply-chain, sales and marketing and the industry is often a training ground for the
development of technical and managerial expertise that is valuable in other industries.\textsuperscript{78}

In 2011, the global automotive industry spend $108 billion on R&D, placing it behind only the
pharmaceutical (US$120 billion) and technology (US$111 billion) industries in R&D investment.
In the main automotive manufacturing industries of Germany, Japan and South Korea, the
automotive industry accounts for 33 percent, 20 percent and 18 percent of total domestic
manufacturing R&D expenditure per annum. It remains at the cutting edge of manufacturing
technology which often cross-pollinates into other industries.\textsuperscript{79}

In recent times Australian designed cars have been designed and build by General Motors
Holden, Toyota Australia and Ford Australia. These manufacturing operations have been
supported by over 200 component, tooling, design and engineering firms. All together the
industry employs over 50,000 people. Cars manufactured by this industry are exported to
Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates, Yemen, United States,
South Pacific, New Zealand, Thailand and South Africa.\textsuperscript{80}

While not competitive with lower cost jurisdictions, the Australian automotive manufacturing
industry is only one of 13 automotive manufacturing industries in the world with the capability
to produce an automobile from concept to delivery. The Australian automotive industry is
capable of taking an automobile, its component systems and sub-systems from a design
concept through manufacture, to safety and durability testing, to final delivery, whole-of-life
service and materials recycling.\textsuperscript{81} In 2010-11 the Australian automotive industry invested A$694
million in R&D.\textsuperscript{82}

Recent announcements by Holden, Toyota and Ford that they will be ceasing vehicle
manufacturing in Australia may have several impacts on automation in the Australian
resources industry:

\begin{itemize}
  \item When the plants closes some technical positions that are made redundant may be
  absorbed into technology deployment and maintenance roles at mining operations
  or more likely, within OEMs that develop, sell and support automated mining
  equipment; and
  \item Some if not many of the 200 domestic component, tooling, design and engineering
  firms that have supported the Australian automotive manufacturing sector most likely
  also support the resources sector. The closure of the automotive manufacturing sector
  may challenge the economic sustainability of some of the component, tooling, design
  and engineering firms weakening the sectors capacity to support automation in the
  resources industries.
\end{itemize}

\textsuperscript{78} Klink, G., Mathur, M., Kidambi, R. and Sen, K. (2013), The Contribution of the Automobile
Industry to Technology and Value Creation: How can the auto industry in India build
momentum for growth?, AT Kearney

\textsuperscript{79} Klink, G., Mathur, M., Kidambi, R. and Sen, K. (2013), The Contribution of the Automobile
Industry to Technology and Value Creation: How can the auto industry in India build
momentum for growth?, AT Kearney

\textsuperscript{80} Austrade (2013), Automotive Components and Vehicle Technologies, Australian
Government

\textsuperscript{81} Austrade (2013), Automotive Components and Vehicle Technologies, Australian
Government

\textsuperscript{82} Austrade (2013), Automotive Components and Vehicle Technologies, Australian
Government
Conclusions

Most certainly component automation is achieving a far greater level of penetration in the mining industry than fully automated mining systems. Despite component automation presenting some operational challenges, this is not surprising given the more attractive automation investment proposition presented by component automation in terms of productivity dividend and drivers of innovation adoption associated with most component automation alternatives to fully automation.

Nevertheless, despite the relative proliferation of component automation in the mining industry, particularly in the form of existing mining equipment that has been ICT enabled and partly automated mining equipment, the mining industry remains a follower of other sectors with respect to the implementation of most automation technology platforms.

It is most likely that the industry will continue to invest in component automation in the form of ICT enabled and partly automated mining equipment, the integration of internal and external databases into systems that inform the operation of that equipment and in new equipment that is designed to generate operational data and new equipment that generates operational data and performs a function based on analysis of that data. As with full or close to fully automated mining systems, this investment will continue to focus primarily on the core mining activities of exploration, mining, processing and downstream transport.

The skills required to implement and support this equipment are being delivered by trade and professional workforce that either has the necessary skills or which is able to adapt to the new technologies through on-the-job experience and training or through training support from equipment OEMs. The mining services sector is also equipped to deploy and service these technologies.

The most significant challenge that is presented to the industry by a greater incidence of component automation is the fact that this will increasingly create the opportunity for the mining industry to transition into a Big Data operating environment. As a result of Australia’s declining participation in STEM education, the statistical, pure mathematics, machine learning, computational chemistry and similar specialist mathematical skills that are required to obtain value from Big Data will likely be in short supply. The fact that other sectors will compete for the same skills and reversing the trend in STEM education is unlikely to bear fruit in the short to medium term, means that these skills will likely be sourced from the international employment market, with some Big Data services outsourced to other jurisdictions.

Part of the solution to creating greater predictability and certainty with respect to meeting automation workforce requirements may reside in a more collaborative cross sector training and skills sourcing strategy with industries that require similar skillsets such as defence.
Appendix 1: Key Findings of Rise of the Machines

While Australia’s vast and diverse natural resources have underpinned the development of a world-class resources industry, it has been technological advancement in exploration, production and processing methods that has resulted in Australia being one of the most important and sophisticated resources industries in the world.

As the Australian resources industries expand in response to unprecedented and likely sustained demand for commodities from the growing economies of the developing world, issues of improved productivity, labour market constraints, OH&S, and access to resources that increasingly present significant technical, environmental and social challenges are strategic and operational issues that are ‘front-of-mind’ for resources company executives. A component of the solution to addressing each of these issues resides in the development and implementation of remote controlled, automated and integrated systems that improve capital and labour productivity, remove humans from harmful or dangerous environments and reduce the externalities that result from resources operations.

A Workforce that Supports New Technologies and a New Operating Environment

Automation can be broadly defined as the intelligent management of a system, using appropriate technology solutions, so that operations of that system can occur without direct human involvement\(^{83}\). The term automation is used somewhat clumsily in industrial applications to describe systems and processes that are characterized by a range of direct human involvement intensity, including processes and systems that have high levels of human involvement through remote control. It is also used to describe the application of information and communication technologies (ICT) to achieve integrated operations.

In essence, automation involves a system of integrated technologies, analytical and processes logic software that intelligently perform a function within a discrete process, across an entire process or across an entire system.

Automated systems in a resources industry operation are differentiated by the relative intensity of field robotics technology, high levels of ‘ruggedisation’ and/or ‘marinisation’, and for mission critical and high OH&S risk tasks, the fact that they require very high levels of systems reliability. Combined, these factors render the development and deployment of automated systems in resources operations technically and economically challenging in many instances.

Perhaps the most important aspect of automated mining and petroleum production systems is the enormous amount of operating data that is produced by these systems. This creates the opportunity to centralize the monitoring and control of all the processes that comprise the operation to a single physical location. The ability to locate some front-line workers to a central,

\(^{83}\) Mining Industry Skills Centre (2010), Automation for Success
and increasingly remote, Operations Centre (OC) where they can apply their knowledge to analysing and interpreting operational data streams from sensors attached to equipment in the field, historical and real-time operational data from across the operation, and other third party data sets, creates a decision environment for effective and efficient problem solving, and opportunities to optimize operations that has not previously existed in many sectors of the resources industry.

The challenge that the resources industry, particularly the mining industry, has had to overcome with respect to automation is that the conventional resources industry workforce does not support the new technologies that are being deployed or the integration of those technologies. The skills, work patterns, leadership models and culture of a typical resources operation is not designed to achieve the optimisation benefits that can accrue from an integrated approach to operations management. This is illustrated conceptually in the figure below.

**Automation and New Technologies**

**Adoption of Automation by the Australian Resources Industry**

The current level of adoption of automation in the resources industry exists on a continuum spanning from the gradual implementation of off-the-shelf technologies to various aspects of operations (nominal automation), to almost total automation and remote control of discrete stages of the production process (partial automation), to mining and petroleum operations that involve very high levels of automation of the process from extraction to market delivery.

As automation systems in the resources industry move along this continuum, the extent of current adoption decreases (more profoundly in the minerals industry than in the petroleum industry). Typically, the proprietary nature of intellectual property associated with the automation system increases, as does the need for new skills and structural and cultural
change in the organization to support the automated environment and optimize its benefits through putting into effect integrated operations. This is illustrated conceptually in the figure below.

**Degree of Adoption of Automation and Implications on the Need for New Skills and Culture**

Estimating the extent and rate at which automation will be adopted across the many different sector and operations types that comprise the Australian resources industry is difficult. This is because there is a tremendous amount of variety in strategy, operational layout, upstream and downstream integration, OH&S issues, environmental issues and general suitability to various degrees of automation across the many operations that comprise each sector of the Australian resources industry, rendering the degree to which automation is compelling to specific operations complex and multifaceted.

The principle driver of adoption of automation in the resources industry is its positive impact on productivity (including OH&S). The impact of automation on productivity is summarised in the figure below.
**Key Drivers of Adoption of Automation in the Resources Industry**

As there are general drivers of a decision to adopt automation in the resources industry, there are also general detractors to that decision. Principally, these are a set of related factors that potentially have a negative impact on project finance and/or operational risk. This is illustrated conceptually in the figure below.

**Impact on Project Economics**
- Impact of higher capital cost on NPV for greenfields projects
- Impact of switching costs on NPV for brownfields projects

**Technology Risk**
- Many new technologies that haven’t been extensively trialled in resources industry applications
- Risk associated with equipment and automation OEM support integration

**Organisational Change**
- New roles and work patterns
- Multi-site integration
- New modes of communication
- New reward systems
- Workforce retraining
- New leadership models

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**Key Detractors to the Adoption of Automation in the Resources Industry**

**Resource Depletion Effect**
Automation counters the negative effect on productivity caused by a decreasing quality of in-situ resources

**Cost of Labour**
Labour costs in the resources industries are high and automation improves the productivity of labour

**Capital Effect**
Resources projects are capital intensive and subject to long production lead times. Automation improves the productivity of capital

**Whole of Operations Optimisation**
Automation produces enormous amounts of operational data that can be used to optimise operations

**Maintenance**
Automation may not reduce the amount of maintenance required but may improve the predictability of maintenance scheduling

**Productivity**

**Improved Resource Access**
Automation facilitates access to resources in environments that cannot be safely accessed by manned equipment

**Reduced Reliance on Conventional Resource Industry Labour Markets**
The change in job functions and location that results from automation provides access to a more diverse employment market

**Reduced Negative Environmental Externalities**
Automation facilitates more precise operations leading to decreased energy consumption and smaller operational footprint

**Improved OH&S**
Automation removes people from dangerous operating environments
While the case for adoption of automation is most certainly company and site specific, we can make some slightly more specific observations at a resources operations type and resources sector level. The figure below summarises current adoption of specific automation technologies and the likely next phase of automation implementation for different resources operations types.

**Extent of Adoption of Automation in Specific Operational Settings**

Similarly, more specific observations can also be made with respect to the status of adoption and specific issues facing adoption of automation for sectors of the resources industry. To date, the adoption of automation within the mining industry has been most prolific in the bulk commodity sectors, particularly with respect to iron ore and coal, with adoption across other sectors being more sporadic. While the case seems adequately compelling for large complex iron ore and coal operations, it is less so for bauxite operations, and highly variable across other sectors. This is illustrated conceptually in the figure below.
Because the case for automation is not equally compelling across all styles of operation or sectors that comprise the Australian resources industry, the adoption of automation by the Australian resources industry is likely to be sporadic and incremental in most cases, rather than the perceived rapid transformation that is sometimes predicted.

Automation and Workforce Structure

As automation is progressively adopted by the resources industry, new technologies will be deployed that are not supportable by the current resources industry workforce skill base, particularly in the case of the minerals industry. The culture of operations that adopt extensive automated systems will change dramatically, again, particularly in the case of the minerals industry. The new culture will be one that is based on a higher incidence of remote control, workforce diversity and integrated, multidisciplinary, data rich problem solving.

There is no doubt that automation will render certain roles in resources operations redundant as it has in other industries. However, there is little evidence to suggest it will result in significant reduction in overall employee numbers. Obvious candidates for redundancy are operators of the equipment that becomes automated, such as drill rigs, loaders, haul trucks and trains. However, even in these obvious cases, some of that workforce will most likely be retrained to operate equipment or sets of equipment remotely, and to oversee components of the automated system. Some unskilled and semi-skilled roles may also be replaced by automation.

The event of automation is unlikely to result in a significant reduction of tradespersons that are employed on a conventional resources operation, as most of the technical issues addressed by tradespersons will remain. For example, while automated equipment may be designed for a higher incidence of ‘change-out’ style maintenance where malfunctioning components are removed and sent off for repair and replaced by a spare component on site, there is already

### Extent of Adoption of Automation in Specific Sectors of the Australian Resources Industry

<table>
<thead>
<tr>
<th>Sector</th>
<th>Automation Development Programs</th>
<th>Primary Applications</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground Coal Industry</td>
<td>Significant industry collaboration with research organisations through Australian Coal Association Research Program</td>
<td>Primarily around long-wall operations, high-wall mining is also highly automated</td>
<td>Automated long-wall shearer face alignment and retreat has resulted in significant productivity improvement OH&amp;S benefits</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>Individual company collaborations with equipment OEMs and research organisations</td>
<td>Total value chain automation (‘blasting to port’)</td>
<td>Significant improvements in productivity only attributable to large, multi-mine operations OH&amp;S benefits Labour market benefits</td>
</tr>
<tr>
<td>Alumina-Bauxite</td>
<td>Individual company collaborations with OEMs</td>
<td>Haulage only as haulage routes are long, but mining is complicated by significant vertical grade variation and downstream processes are already highly automated</td>
<td>Limited because mining is a relatively small portion of the total cost of producing alumina</td>
</tr>
<tr>
<td>Other Sector</td>
<td>Complicated by significant diversity in a range of factors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Automation Development Programs

- **Primary Applications**
  - **Underground Coal Industry**
    - Primarily around long-wall operations
    - High-wall mining is also highly automated
  - **Alumina-Bauxite**
    - Haulage only as haulage routes are long, but mining is complicated by significant vertical grade variation and downstream processes are already highly automated
  - **Iron Ore**
    - Total value chain automation (‘blasting to port’)

- **Benefits**
  - **Underground Coal Industry**
    - Automated long-wall shearer face alignment and retreat has resulted in significant productivity improvement
    - OH&S benefits
  - **Alumina-Bauxite**
    - Limited because mining is a relatively small portion of the total cost of producing alumina
  - **Iron Ore**
    - Significant improvements in productivity only attributable to large, multi-mine operations
    - OH&S benefits
    - Labour market benefits

### Complicated by significant diversity in a range of factors

- **Underground Coal Industry**
  - Physical scale
  - Throughput
  - Mine life
  - Ratio of mining cost to total costs
  - Production goals
  - Operational layout
  - Type of mining process
  - Degree of OH&S risk that can be mitigated by automation

### Other Sector

- Complicated by significant diversity in a range of factors including:
  - Physical scale
  - Throughput
  - Mine life
  - Ratio of mining cost to total costs
  - Production goals
  - Operational layout
  - Type of mining process
  - Degree of OH&S risk that can be mitigated by automation

**Underground Coal Industry**

- Automation Development Programs
- Significant industry collaboration with research organisations through Australian Coal Association Research Program
- Primary Applications
- Primarily around long-wall operations
- High-wall mining is also highly automated
- Benefits
- Automated long-wall shearer face alignment and retreat has resulted in significant productivity improvement
- OH&S benefits

**Iron Ore**

- Automation Development Programs
- Individual company collaborations with equipment OEMs and research organisations
- Primary Applications
- Total value chain automation (‘blasting to port’)
- Fundamentally, automation of a complex logistics exercise
- Benefits
- Significant improvements in productivity only attributable to large, multi-mine operations
- OH&S benefits
- Labour market benefits

**Alumina-Bauxite**

- Automation Development Programs
- Individual company collaborations with OEMs
- Primary Applications
- Haulage only as haulage routes are long, but mining is complicated by significant vertical grade variation and downstream processes are already highly automated
- Benefits
- Limited because mining is a relatively small portion of the total cost of producing alumina
a high incidence of this style of maintenance in modern resources industry equipment. Routine mechanical issues such as oil leaks will still require maintenance attention on site. Increased automation may result in an increase in the number of electrical tradespersons required on site to support change-outs and other ICT systems. However, different demands from tradespersons will most likely be best addressed through modifications to trade qualifications and additional training. The removal of driver error may result in improved predictability of maintenance scheduling.

While the precise impact of automation on workforce size and structure is not entirely clear, there is general consensus among operators that the following three roles that are not usually associated with resources industry, particularly mining operations, but are commonplace in other automated environments, will become increasingly important operational roles in the resources industry:

- **Automation Technician**
  The role of an automation technician is to build, install and maintain automated machinery and equipment. It is largely a systems integration role, with electrical tradespersons still being required to perform functions such as wiring and mechanical tradespersons still required to address mechanical issues. If deployed on an operating environment today, it is expected that an Automation Technician would be heavily reliant on support or direction from other experts (engineers and tradespersons) to perform many of the tasks.

- **Mechatronics Engineer**
  Mechatronic technologies are central to field robotics and the application of automated and remote control systems to resources industry operations. Mechatronics engineering is a multidisciplinary field that combines electrical, mechanical, computing and software engineering to create expertise in designing, building, deploying and maintaining electromechanical devices such as robotics. A particular skill set that is common to mechatronics engineers that is crucial to many resources operations automation programs is data fusion expertise. Because highly automated resources industry operations produce enormous volumes of data from heterogeneous data streams, the ability to write software code that can interpret and integrate those heterogeneous data streams is critical to not only the operation of automated systems, but also optimizing their benefits.

- **Operations Optimisation Manager**
  As resources operations become more automated and the immediate benefits of the automation program are realized, significant additional benefits can be attained through optimization, as has been the experience of other largely manual processes that have achieved high levels of automation. This role applies expertise in logistics and process optimization to achieve optimal whole of operations productivity and other benefits, and is performed by an operations optimization manager.

Previous analysis has estimated that on the basis that 50 percent of the 500 resources industry sites in Australia required 3 to 5 automation technicians, that 1,500 such roles would need to be filled. In light of the discussion in this paper on the complexities associated with the adoption of automation in the resource industry, it is unlikely that demand for automation technicians will emerge to this extent in the short term. Anecdotally, it appears the functions of an automation technician are currently being filled by resources companies implementing automation from two key sources:
• Electrical tradespersons who acquire the additional skills required to perform the automation technician role through experience and some on-the-job training. It was noted from the interviews associated with the study that this pathway will not be adequate in the longer-term because many trade staff may struggle to attain the higher-level skills that are required for the job; and

• Technicians operating in other industries that have higher-level automation related skills. In the mining industry a significant portion of such technicians seem to be recruited from the Army, and in the case of the oil and gas industry, from the Navy’s Submarine Service.

**Implications for Vocational Education and Training**

The current absence of a resources automation technician qualification is primarily the function of the following two factors:

• **Absence of an immediate market**
  The development and delivery of courses by training and education organizations is a function of the market demand for those courses. It is likely that there is currently not a big enough employment market for graduates with a comprehensive set of skills in resources industry automation and as such limited student demand. This is a function of the fact that extensive automation is currently not widely adopted, and that where extensive automation is adopted, skills and expertise gaps are being filled by electrical engineers, or engineers and tradespeople with automation skills that have been developed in other industries such as defence. It is unlikely that institutions will invest in resources industry automation programs to any great extent until there is an adequate addressable market for the courses.

• **Commercial-in-Confidence nature of many automation programs**
  Most of the extensive automation programs that are currently being developed and deployed are being done so by large multinational mining companies seeking first mover advantage in automation. As such, the intellectual property associated with these programs is being treated as commercial-in-confidence. The training of deployment and maintenance staff for these programs is typically conducted in collaboration with an equipment OEM or under an exclusive arrangement with a specific institution of training and/or education. This makes it difficult for other institutions to develop and validate general resources industry automation curricula.

At a mechanical trade qualification level (Certificate III), it is possible to cover some basic electrical concepts and to obtain a restricted electrical license. However, this is significantly deficient with respect to the skills required of an automation technician. An electrical trade qualification covers the required electrical skills more comprehensively including control technologies such as PLC, but still falls short of the required skill set. While a dual trade qualification (mechanical and electrical) would substantially progress a tradesperson toward the required qualified skill set, it will also still be deficient.

It is therefore not surprising that both public and private Registered Training Organisations are trending toward creating a qualification for an automation technician as a post trade qualification, typically at Diploma level, but in some cases associate degrees. There is also a view that most of the material for this post-trade qualification could be compiled by combining content from a range of existing electrical and mechanical Certificate IV and Diploma
qualification curricula. Additionally, some course structures offer units in working and communicating in different cultures, and facilitate remote delivery of the course.

Implications for Higher Education

Generally speaking, it would seem that two different pathways are possible for the training of engineers with adequate skills and expertise to work with more automated resources industry systems:

- **Mechatronics Engineering in Resources Undergraduate Degree**
  It would seem that the main challenge that resources companies face in employing a mechatronics engineering graduate is the lack of expertise in mining or hydrocarbon production processes possessed by the graduate, as conventional mechanical and electrical engineering can be harnessed by employing mechanical or electrical engineers. As such, there is a possibility that a specialised mechatronics engineering in resources undergraduate degree may emerge. This is unlikely to eventuate until the adoption of automation is adequately comprehensive so that a specific new resources industry technical profession in automation emerges.

- **Post Graduate Qualification**
  In the short to medium term, it is more likely that a post-graduate qualification such as a graduate diploma or masters degree in mechatronic engineering that is focused on developing the required automation expertise in mechanical, electrical, mining or oil and gas engineering graduates will be the most practical pathway for relevant formal qualifications.

The high incidence of commercial confidentiality that surrounds proprietary automation programs is making it difficult for universities to assess future skill needs and determine the capability that needs to build into faculties for the delivery of future programs. While some industry automation programs are working directly with specific universities and other training organizations to develop packages for their employees, it is unlikely that wider consultation will occur until automation is more widespread.

An analysis of Australian universities that offer programs in mechanical, electrical, mechatronic, mining and petroleum engineering highlights the following:

- Within the combined curricula at each institution there appears to be a plethora of course material that, subject to the requirements of the specific institution’s academic council and Engineers Australia, could potentially be reconfigured to at least form the basic formal qualifications at either an undergraduate or graduate level to meet the foreseeable technical professional needs of the resources industry as demand dictates;

- In all cases, the electrical and electronic engineering curricula most closely resembles that of the mechatronics curricula, noting that in some cases, a limited number of subjects more typically taught as part of a mechatronics or electrical engineering degree are also taught in the mechanical engineering degree; and

- In all cases, the content in the mining engineering and petroleum engineering curricula is the most removed from the mechatronics degree curricula. However, at least one university is contemplating developing an elective mechatronics stream as part of their bachelor of mining engineering program.
Appendix 2 – Growth of the Multimodal Logistics Industry

Multimodal logistics systems are performing an increasingly fundamental role in world trade, enabling significant reduction in transit times, minimisation of congestion, reduced logistics costs and safe movement of goods\(^84\). Containerised transport is the backbone of multimodal logistics systems. For example, intermodal traffic in the United States increased from 6.2 million units (containers and trailers) in 1990 to 11.8 million units in 2012\(^85\). As illustrated in the figure below, this growth in multimodal traffic has been principally in containerised traffic\(^86\).

**Growth in Intermodal Traffic in the United States**

While containers are the principal vector of multimodal transport, the following modes of multimodal transport also play an important role, particularly Roll-on-roll-off\(^87\):

- **Roll-on-roll-off**
  Roll-on-roll-off (Ro-Ro) combines sea and road transportation and is typically used for cargo such as wheel based vehicles or heavy and over-dimensional cargo. Cargo is simply driven into storage capacity inside a large vessel via a ramp at the point of

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\(^85\) Bentz, B (2013), ‘Intermodal: Getting serious about multi-modal optimisation’, *Supply Chain Management*

\(^86\) Association of American Railroads IN: Bentz, B (2013), ‘Intermodal: Getting serious about multi-modal optimisation’, *Supply Chain Management*

\(^87\) Deloitte (2012), *Intermodal and Multimodal Logistics Knowledge Paper*
loading and then driven off at the destination. The cargo may be self-propelling such as an automobile or stored on a trailer that is driven into the cargo-hold by a customised prime mover and disconnected.

- **Lighter Aboard Ship**
  Lighter-Aboard-Ship (LASH) transport is the combination of open-ocean and inland waterway transportation. Barges operating on inland waterways can be loaded with cargo and then loaded onto a LASH and transported across sea to the destination port where they are unloaded to carry the cargo further into the hinterland via a canal or river system. The key disadvantage of this mode of transport is the cost of LASH vessels.

- **Piggyback/Trailer Train**
  This is a system of unitised multimodal land transportation that combines the speed and reliability of rail for the long-distance component of the haul and the door-to-door flexibility of road transport for collection and delivery. Cargo is packed in trailers and hauled by tractors to a railway station. At the station, the trailers are moved onto railway flat cars and the transport tractors are disconnected. At destination, tractors again haul the trailers to the warehouses of the consignee, facilitating a final leg of road transport for the delivery.

- **Sea Train**
  Similar to a Ro-Ro system, a rail car is used in place of the Ro-Ro vehicle so that geographically separated rail systems can be connected by the use of an ocean carrier.

A multimodal logistics hub is a facility (or network of facilities) that gives effect to multimodal transport and logistics. By virtue of optimal access to road, rail, pipeline, short-sea, river and air transport infrastructure, modern seaports tend to perform this function.

As illustrated in the figure below, the event of multimodal transport has an even more profound impact on external trade than that of containerised ports in both developed and developing nations.

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89 Standing Committee for Economic and Commercial Cooperation of the Organisation of Islamic Cooperation (2013), Global Trends and Policies in Multimodal Freight Transport, Organisation of Islamic Cooperation
Growth in External Trade - The Events of Containerised Ports and Multimodal Container Terminals

- First 20 Years of Containerisation of Ports
- Event of Multimodal Container Transport

**IMPACT OF CONTAINERISED PORTS AND MULTI-MODAL CONTAINER TERMINALS**
Appendix 3: Innovation Characteristics that Drive Adoption

There is a significant body of empirical evidence that supports the notion that the following five factors describe 49 to 87 percent of the variance in rate and extent of adoption of any innovation in any industry:\(^\text{90}\)

- **Relative Advantage**
  Relative advantage refers to the degree to which the adopter perceives the innovation as being better than the current practice or technology, which can include doing nothing. The improvement can be measured objectively or subjectively by the adopter according to a range of criteria including economics, convenience, safety, prestige etc. Innovations demonstrating a strong relative advantage are more likely to be adopted.

- **Compatibility**
  Compatibility refers to the degree to which an innovation is perceived as being consistent with the existing values, experiences, needs, processes and business systems of the adopter. Innovations that are compatible are more readily adopted.

- **Complexity**
  Complexity refers to the degree to which an innovation is perceived as being difficult to understand and use. The more simple the target adopter perceives the innovation is to understand and use, the more likely the innovation will be adopted.

- **Trialibility**
  Trialibility refers to the degree to which an innovation may be experimented with on a limited basis to reduce the risk that in practice it does not deliver on the adopter’s expectations of relative advantage and compatibility. Innovations that can be trialed on a limited basis before an adoption decision is made are more likely to be adopted.

- **Observability**
  Observability refers to the degree to which the results of an innovation are visible or measurable and the degree to which the benefits can be directly linked to the adoption of the innovation. The easily and rapidly potential adopters can observe the results of using the innovation the more likely they are to adopt.

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