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CRC MINING
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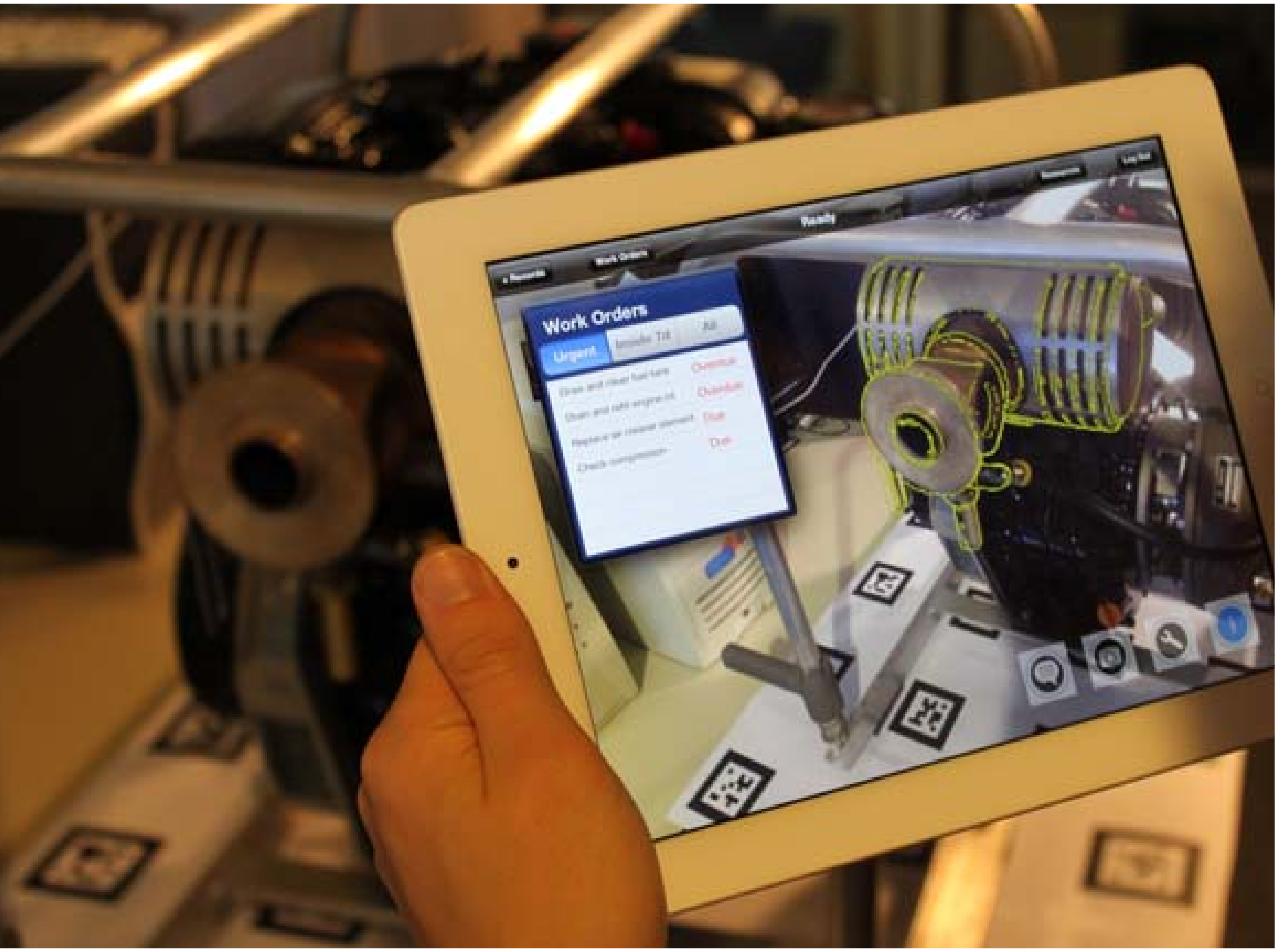
Maintainer of the Future

How the evolution of technology and asset management will change the training and role of the modern maintainer



INTRODUCTION

In the last two decades we have seen significant changes in how assets are operated due to advances in process control, remote operations systems, and the development of autonomous assets. In contrast, the nature of maintainers' day-to-day work has changed very little. Engines still need lubricated, motors wired up, pipes welded and sensing systems repaired. However we may be at a tipping point as a combination of business drivers (cost, productivity, safety) and technical developments (automation, augmented reality, real-time diagnostics) combine to change the nature of maintenance work. This paper examines these drivers and looks at how these might influence the work and training of the maintainer of the future.

This study is divided into two sections as follows:

1. **Drivers of change**
   - What changes are expected to asset design, technical support equipment and organizational processes in the next 15 years?
   - How will these developments affect the role of maintainers and their day-to-day tasks?
2. **Training of maintainers**
   - How maintainers are currently trained in Australia?
   - What are the enablers and barriers to ensure an appropriate maintenance workforce for the changes expected?

This work collected data from a) workshops with industry professionals, b) interviews with professionals from a range of sectors and government bodies, and c) reports and technical literature. The work is funded by CRC Mining and hence the primary focus of the recommendations is towards the mining sector. However, in considering drivers of change and training, the report has looked at global and national trends and across sectors.

KEY FINDINGS

Drivers:

- Three key drivers of change to the nature of maintenance work are asset design, development in technical support equipment and organisational strategy – especially directed towards improved safety.

- The safety and cost pressures to remove operating people from the mine site are also raising questions about how similar pressures can be used to reduce the exposure of maintainers to hazards in the operating environment. Barriers to change can be overcome through a rethinking of roles in the maintenance workforce and through equipment design changes.

- The Original Equipment Manufacturers (OEMs) are a key part of any change in the day-to-day work of maintainers. Their designs determine the maintainability of the system, their sensing systems influence what data is collected, and the interoperability of components and software influence training requirements.
- There are commercial opportunities for OEMs to move from retail-only to a whole-of-life retail and service relationship that leverages the data they collect on the asset. This is common in some industries and has resulted in significant changes in who maintainers work for, with maintainers moving to the OEMs, contractors or specialist repair providers and fewer maintainers (needing different skills) left on the operating site.
- The increased use of sensors and embedded systems is opening doors to proactively manage asset system health using big data techniques. Proactive maintenance requires a different culture and different skills in the maintainer workforce compared to one used to working in a reactive environment.

Training:

- The Certificate III qualification is required for entry into most maintenance-related roles in the Australian mining sector. Most training after Certificate III in the mining sector is being done outside of the VET sector. Much of this is organisational, equipment or vendor specific. As a result, maintainers are developing individual skill sets or portfolios. These portfolios are not aligned with nationally accredited qualifications.
- Assurance of competence is emerging as a major challenge. The concern is how employers assure themselves that their employees and contractors demonstrate appropriate behavioural and technical competence on the job. A qualification confirms that the maintainer attended a particular training course or was assessed as being competent in a specific training situation, which may not always translate to competence in the field.
- An ability to use computers and access equipment status information through digital interfaces is now a core requirement for most maintainers. The skills required to conduct basic troubleshooting and diagnostics using a range of tools are widely reported as being in need of further development across all maintainer trades.

RECOMMENDATIONS

- Industry needs to rethink the role of the maintainer as being a single role filled by individuals with varying degrees of expertise in a wide range of tasks, and consider that the "maintainer of the future" may encompass a number of quite distinct roles. These are first-responders, equipment care technicians, diagnosticians, and specialists. The latter will likely be employed by OEMs and specialist repair facilities.

- Graduate engineers have many of the analytical skills required to perform the diagnostician role. They have not traditionally looked towards a maintenance role on graduation and with the tightening job market they should be encouraged to do so.

- There should be a concerted effort by the mining sector to develop a pathway to allow maintainer skill sets obtained through non-accredited company-focussed training to be translated into nationally-recognised qualifications.

- More thought should be given to maintainability assessment when equipment is purchased and systems are designed. This is a safety imperative and will help to increase the focus of OEMs on improving maintainability.

- There is an opportunity to develop a common approach across organisations that work in the same asset sectors (both operators and contractors) to defining technical and behavioural competences for maintainers. These competences should be developed with a view to the roles maintainers will have in the future, rather than be wedded to the ideas of the past.

- Major employees of contractors should examine the potential for a shared approach to competence assurance to avoid significant duplication of effort. This suggestion goes beyond the processes currently in place that record and check qualifications. To do this requires a better understanding and agreement as to what key maintainer competences are and how they can be assessed and assured.

- Maintainers represent a significant proportion of people who are involved in safety incidents and fatalities in the mining industry. Any moves away from the reactive work environment pervasive on many mine sites today to a more controlled and planned environment will help to improve these statistics and reduce the potential for harm.

- As an industry, mining needs to consider how to ensure that maintainers perform the *right role* with the *right skills* doing the *right work* at the *right time* in the *right way*.

DRIVERS OF CHANGE

Three drivers of change were identified during a workshop for 60 asset managers, operations and maintenance personnel held in Perth in November 2013. These are shown in Figure 1.

1. Asset design
2. Organisational strategy
3. Technical support equipment

Elements within each of these that are likely to impact on maintainers are discussed in the following section.

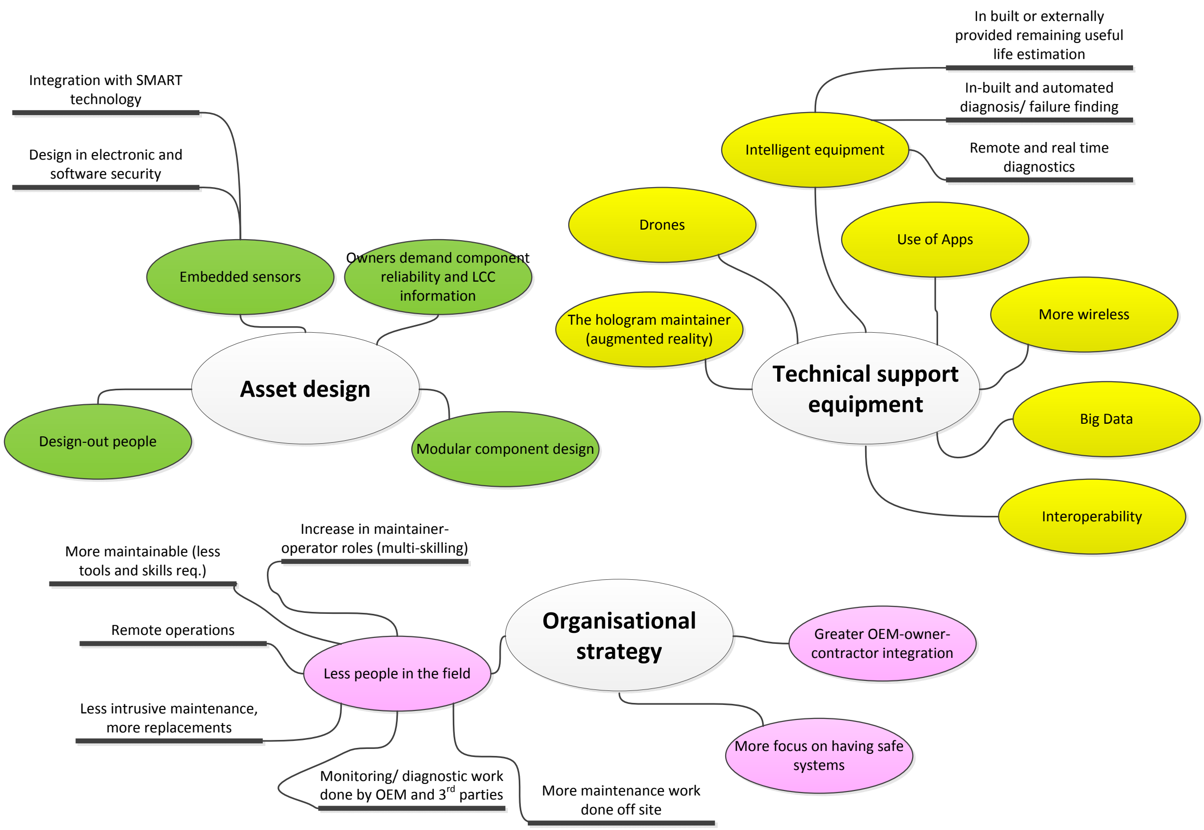


Figure 1: Drivers of change to the role and day-to-day tasks of maintainers

ASSET DESIGN: **EMBEDDED SENSORS**

The last ten years has seen a significant increase in the use of embedded sensors on assets in both heavy industry and in consumer products. The rapidly growing development of diagnostic, prognostic and communication systems has led to products such as Integrated Vehicle Health Management (IVHM), Boeing's Airplane Health Management System (AHM), Rolls Royce's Equipment Health Management System (EHM), Caterpillar's Vital Information Management System (VIMS), Phantom Works at Boeing, and GE's Health Usage and Management System (HUMS). These systems and similar offerings are now applied to vehicles from the Joint Strike Fighter to commercial haulage trucks [5-7].

The relatively low cost of adding sensors and of storing the data means that we now have more data than we can use, and the struggle for many organisations is turning this data into information. For most mining companies, there are additional challenges with getting maintainers to put appropriate data into the current systems, dealing with legacy data and systems, and having the business processes that support using the results of the analysis.

However, in time, we can expect this to change. When it does, organisations should have the ability to better predict the performance of their assets and to improve maintenance delivery through a greater focus on preventative work [8]. This will result in less need for reactive maintenance work and an emphasis on controlled execution of planned work. In addition, it is anticipated that maintainers (enabled by these embedded sensors) will be involved in the monitoring and diagnostics of asset health management. This will require maintainers to develop new skills and behaviours in many areas, as discussed in the following sections.

ASSET DESIGN: **DESIGN OUT PEOPLE - AUTONOMOUS EQUIPMENT**

The Australian mining industry is on an “inescapable and unstoppable march towards autonomy” [9]. Over the last 5 years, there has been a significant push to reduce the number of people in remote operations through the use of autonomous equipment. Significant progress has been made by both Rio Tinto and BHP Billiton Iron Ore through the former’s Mine of the Future program and the Remote Operations Centre at the Perth airport, and through the latter’s IROC centre in the Perth Central Business District. These centres operate equipment including trucks, drills, ore-car dumping and conveying that are located over 3000 km away in the Pilbara. There have been several drivers for this development including safety, reduced personnel costs (flights, accommodation, housing and site allowances), as well as operational benefits of higher utilisation and less operational wear on the equipment.

Although it is early days, indications are that autonomous trucks experience less variability in how they are operated and less wear and tear due to the removal of the human element. An example of this is optimal acceleration and deceleration. This should assist a move to a more controlled day-to-day environment for the maintainers allowing for a greater focus on planned and predictive work.

ASSET DESIGN: **MODULAR COMPONENTS**

When a group of asset managers and engineers comes together, the idea of modular design is often identified as one of the next big things. However, in many industries, little progress has been made in this area. Most heavy mobile equipment is no easier to maintain today than it was 20 years ago. It is difficult to see the business case for OEMs to make products more maintainable. Many receive substantial income from sales of spare parts and/or specialist servicing and overhauls. As one OEM said when interviewed, “When we design components our first consideration is: Can we manufacture it? Not: Can we maintain it?”

Having said this, in some sectors (most notably commercial aviation) there has been significant progress in the use of modular design to improve maintainability.

Changes towards modular designs would have knock-on effects for maintainers. The emphasis switches from repair to one of diagnosing which module to replace and then executing the replacement. This replacement activity may be done by maintainers with a lower skill set than that required for the repair.

ASSET DESIGN: **TECHNICAL SUPPORT EQUIPMENT**

There are a lot of exciting developments associated with technical support equipment, only some of which are shown in Figure 1. Many of these, such as drones and augmented reality, are already being used in certain sectors, notably military and aviation. The use of predictive analytics and reasoning algorithms in centralised health management systems such as IVHM can provide an indication of remaining useful life and real-time diagnostics for components. This technology could apply to any company that manufactures or services complex machinery, and the timeframe for extension into other sectors is largely dependent upon training and the ability to retrieve and interpret "big data". At present, interoperability remains a barrier but groups like CSIRO, CRC Mining and GMSG (Global Mining Standards and Guidance group) are working on international standards in this area. While the attractions of integrating data and technology seem obvious on paper, there are still practical problems to solve. Many OEMs have adopted a strategy of designing proprietary technology with limited, sometimes no, interconnectivity.

These developments taken together could significantly impact the nature of maintenance work. As the predictability of work improves through more knowledge of the health and performance of the asset, work becomes less reactive and there is more demand for preventative work. At present, a significant focus in maintenance training is on repairs rather than on the skills required to diagnose and respond to changes in asset performance prior to failure. These traditional ‘‘fail and fix (FAF)’’ maintenance practices are making way for a ‘‘predict and prevent (PAP)’’ e-maintenance methodology [10].

Qantas combine the use of diagnostics software and a digital maintenance logging platform for its entire Boeing and Airbus fleet. The software provides Qantas with real-time data on aircraft health and forecasts maintenance costs, while the maintenance interface logs service history, and delivers instructions, required parts, certification and so on. In this respect, the system empowers Qantas with a whole-picture view of the real time state-of-maintenance and compliance at the point of execution, which can significantly reduce human error, downtime and costs, and increase safety. Within the mining industry, the potential to use current software platforms in a similar way is there, but unrealised.

This emphasis on diagnostics and troubleshooting rather than the physical manipulation of equipment is also now being supported remotely, using tools such as location-tagged equipment and augmented reality [11]. Advances in display technology, information mobility and mobile devices such as tablets and “Google glasses” can now provide specialist assistance from a control centre, database or program to a maintainer on the ground. This then changes the role and required skill set of the technician. We usually have very little idea of how maintenance work is done, but the use of these devices will allow for improved documentation of work that can subsequently be used to increase the quality of work, consistency of approach as well as to support training. Developments in simulation, initially directed at training operators and pilots, are now being considered for maintenance professionals as well.

ORGANISATIONAL STRATEGY: **LESS PEOPLE ON SITE**

There have been a number of major initiatives in the last 10 years, particularly in the resource sector, to move people off remote sites. There are several obvious reasons for this, the first being health and safety. If the work can be done remotely using automation then there are potential benefits through reduced exposure. The second is cost. Transport and accommodation in remote areas is expensive, and wages also tend to be higher. However, the move of operators out of remote locations and into centralised operations centres in major cities has implications for who is left on site, who has to travel to site and when, and the nature of their work. It is likely that these changes will encourage organisations to develop more multi-skilled or hybrid roles; for example operator-maintainer and cross-trade roles.

Because of the potential loss of some skills, there will be a rethink about what maintenance work can be done on site and if more complex repairs should be done off-site. Potentially, this will reduce the number of maintenance staff on-site needed for reactive work and chronic repairs. It could also increase the focus on technology-enabled maintenance support staff in central facilities such as the remote operations centres.

ORGANISATIONAL STRATEGY: **TOTAL SERVICE PACKAGES**

Total service packages (TSPs) are arrangements between the OEM and the operator, whereby the OEM offers servicing and maintenance over the life of the asset. There are a few examples of this in the mining sector and it is widely used in the aviation and defence sectors. This has resulted in a changes to who maintainers work for rather than what they do. Compared to 20 years ago, organisations that own the asset no longer retain the capability to do more than just minor repairs – for which they retain skeleton maintenance staff. The OEMs in this situation usually monitor the assets across the globe from central locations, provide on-call or permanently on-site technicians for troubleshooting, and transport the assets to workshop facilities for renewal and repairs. In these situations, the OEMs are responsible for the development and training of maintainers. There is quite a different set of skills required for maintainers in these repair and overhaul facilities to those working for the owners on site.

> ***Maintenance labour accounts for over 50% of overall labour costs at a typical surface mine in Canada [3]***

To a certain extent, greater OEM-owner cooperation is occurring in the autonomous truck developments in the Pilbara, as organisations have elected to work with one or another of the major OEMs in this area. The drivers for this are competitive advantage through superior technology or superior deployment of the technology. It perhaps too soon to see how this might affect the role of maintainers or who employs them, though we are seeing the demand for new skill sets to deal with the autonomous equipment and other advances in technology.

ORGANISATIONAL STRATEGY: **SAFE SYSTEMS**

The physical nature of the maintenance work is associated with the main classifications used for serious injuries work statistics (over/strenuous movement, caught by or between) [12]. In the ten years to 2012, there were 52 fatalities in the WA mining industry, of these 36 (69%) were maintainers and operators [2].

Maintainers in the mining industry work in an environment which, in many organisations, is quite reactive. Although maintenance groups aspire to develop work packages, to plan and schedule, and to execute the work in an organised and controlled way, this is not evident in practice [13]. The boom of recent years, which has favoured construction of new facilities and a significant focus on production output, has hampered any executive focus on improving maintenance practices. However, in the post 2012 period, the focus has shifted to productivity, and maintenance is seen as an area in which considerable improvements can be made.

There is also increased attention being directed to how maintainers work, and in particular to health and safety. The size and weight of components has increased considerably, especially on mobile mining equipment, but the manual handling approaches have not. There is now some focus on looking at reducing the need for the lifting/ holding of heavy loads and working in cramped or difficult-to-access spaces. We are seeing the introduction of new tools such as the use of robotics to assist with mill liner, conveyor idler and haul truck tyre replacement. These demonstrate consideration given to design to aid maintainability, and an emphasis on adhering to safe working procedures. Given time, the introduction of these measures will make the work of maintainers less physically demanding, and potentially attract different groups of people into the field.

Between 2002 and 2012 there were 52 fatalities in the WA mining industry; of these 36 (69%) were maintainers and operators

TRAINING FOR MAINTAINERS

A key element in ensuring that assets deliver on organisational objectives is the ability to restore asset functionality when it deteriorates and to execute proactive work to ensure assets perform as required. Maintainers are at the front line of both of these activities; they are the only people who have the skills and experience to perform this work. The quality of maintainers' work directly impacts future asset reliability and their competence and speed of work determines system availability. Despite the value they can add (or destroy), there has been relatively little research into how maintainers learn and how they work. This section provides an overview of the training environment for maintainers, particularly in the mining sector. It also looks at relevant data and trends, and at what research is available about how maintainers acquire new skills.

BASIC QUALIFICATIONS FOR MAINTAINERS

The entry-level (trade) qualification for most maintainers is AQF Certificate Level III. A description of the skills and their application for Certificate III and the following level, Certificate IV, is provided in Table 1. The volume of learning of a Certificate III may be 1-2 years depending on prior learning, but up to 4 years is typically required when done through a program of indentured training/employment by school leavers [14]. The focus of Certificate III is on the ability to complete routine activities in stable situations within established parameters.

Table 1: Australian Qualifications Framework descriptors for Certificate III and IV [14]

	Certificate III	Certificate IV
Skills	Will have a range of cognitive, technical and communication skills to select and apply a specialised range of methods, tools, materials and information to: • complete routine activities • provide and transmit solutions to predictable and sometimes unpredictable problems	Will have a broad range of cognitive, technical and communication skills to select and apply a range of methods, tools, materials and information to: • complete routine and non-routine activities • provide and transmit solutions to a variety of predictable and sometimes unpredictable problems
Application of knowledge and skills	Will apply knowledge and skills to demonstrate autonomy and judgement and to take limited responsibility in known and stable contexts within established parameters	Will apply knowledge and skills to demonstrate autonomy, judgement and limited responsibility in known or changing contexts and within established parameters

POST-TRADE QUALIFICATIONS FOR MAINTAINERS

Referring to Table 2, we see that 70% of technicians have Certificate III or Certificate IV qualification. However, Table 3 shows that within this 70%, 92% have Certificate III and only 8% have Certificate IV. The number of Certificate IVs qualifications seems dramatically underrepresented. Additionally, there was a 21% decrease in student commencement at a Diploma level (AQF Level 5) or higher between 2005 and 2010. During this period, the number of domestic students commencing engineering studies in Australian universities increased by 35% [15]. See Appendix 1 for more data regarding the number, sectors and demographics of maintainers.

Table 2: Qualifications for technicians in the mining sector (Australian Bureau of Statistics, 2011 Census)

	Certificate I & II	Certificate III & IV	Diploma	Advanced Diploma and Associate Degree	Bachelor Degree	Certificate Level, nfd	Level not stated, inadequately described or not applicable	Total
Building/ Engineering Technicians	107	5013	780	483	604	243	3010	10240
ICT and Telecomms Technicians	9	87	42	12	119	12	127	408
Automotive/ Engineering Trades nfd	0	228	12	4	0	0	14	258
Automotive Electricians/ Mechanics	6	1379	8	13	19	3	187	1615
Fabrication Engineering Trades	14	2717	17	15	15	12	392	3182
Mechanical Engineering Trades	48	12211	241	147	183	37	1800	14667
Electricians	17	4629	166	118	58	9	493	5490
Electronics/ Telecomms Trades	0	600	46	40	21	3	136	846
Other Technicians	55	2414	244	186	396	72	1568	4935
Total	256	29278	1556	1018	1415	391	7727	41641
% of Total	1%	70%	4%	2%	3%	1%	19%	-

Note: nfd stands for 'no further description'

Table 3: Proportion of technicians in the mining sector holding Certificate III or Certificate IV qualifications (Australian Bureau of Statistics, 2011 Census)

Mining Sector	Certificate IV	Certificate III	Total
Technicians and Trades Workers nfd	9%	91%	455
Automotive Electricians and Mechanics	2%	98%	1379
Mechanical Engineering Trades Workers	2%	98%	12212
Electricians	5%	95%	4630
Building and Engineering Technicians	13%	86%	5014
ICT and Telecommunications Technicians	31%	69%	86
Automotive and Engineering Trades Workers nfd	2%	98%	226
Fabrication Engineering Trades Workers	2%	98%	2716
Electrotechnology and Telecommunications Trades Workers nfd	10%	90%	248
Electronics and Telecommunications Trades Workers	7%	93%	353
Average	8%	92%	2732

Note: nfd stands for ‘no further description’

The authors offer two explanations for the lack of enrolment in post-trade (after Certificate III) qualifications. First, more students are opting to pursue higher education at university, rather than at RTOs. In 2011, there were 6607 domestic students completing Bachelor degrees of Engineering, up from 6237 the previous year and 6063 the year before that [16]. Between 2006 and 2011, the total supply of engineers increased by 63,275, equivalent to compound growth of 5.6% per year [16]. With the recent end to Australia’s minerals boom, there are now more graduate engineers searching for full time work (see Appendix 2 for graph of engineering graduates seeking full time employment). This will be discussed later as a possible solution to some current skills gaps in the maintenance area.

In 2011-2012, 78 per cent of mining companies offer some form of structured non-accredited training, and 82 per cent of mining employees participate in such training [1]

Secondly, and perhaps more significantly, this lack of subscription to post-trade VET education is due to the move towards unaccredited training – particularly in the mining sector. The minerals industry now spends a significant proportion of its training dollar (total training expenditure estimated as $1.15 bn in 2011/12) on private company training outside of the VET sector [1].

While providing in-house training is a convenient short-term solution from the company's perspective, the net effect is that maintainers acquire a "pick-and-mix" set of (often unrelated) skills training, which at present does not translate to any nationally-recognised and portable qualification. It is also difficult to scale this type of training quickly if demand increases, as the original training organisation may not have the capacity to deliver on a national scale. Both of these factors can have industry-wide ramifications; they can result in skills crises and hinder growth. Labour mobility (through such forms as staff relocation, Fly-in Fly-out (FIFO) employment agreements and skilled migration) is an important part of the success of Australia's mining industry. It provides the flexibility that allows Australia to secure major resource investments. Labour mobility has been critical in enabling the Australian minerals sector to seize the opportunities of higher global demand for minerals commodities over the past decade [1].

The training provided by the mining sector focuses on ensuring that the maintainer has the right skills for specific tasks for that employer. As one industry executive said, "Why would we want to train them and have them go and work for someone else?" The training might be technical – for example how to service a particular equipment model; safety-related – for example confined space entry; or related to new legislation or company policies. There is a record kept that the maintainer has attended the training, and in some cases there is some form of assessment or requirement to demonstrate the skill. One result of this is that many individual's training pathway is different, with each maintainer accumulating a unique set of training certificates. For someone looking to hire the maintainer, there are questions about the quality of the training, how much the maintainer absorbed, and whether the maintainer can be considered competent. As a result, assurance of competence is emerging as a key challenge, and is discussed in the following sections.

There was a 60% increase in the number of technicians and tradesmen in the mining sector in 2011 compared to 2006 [4].

STRUCTURE AND REGULATION OF THE TRAINING ENVIRONMENT

The VET policy environment affects all industries and (directly or indirectly) all organisations who employ maintainers. It establishes the framework for skills development, and plays a determinative role in establishing the efficiency and effectiveness of investment in skills which, over the long term, affects the skills base of the workforce [17]. Since 2009, there has been a reform agenda which has reviewed many aspects of the Australian VET System. This has resulted in significant changes in the broader VET environment, including policy frameworks, endorsement schemes, regulatory requirements and management systems. A comprehensive summary of the various reviews and reforms is available in [17]. The last decade has been characterised by a dynamic and often uncertain policy environment for the VET sector, with significant changes to VET funding by several State governments in response to fiscal constraints. This is forcing a rethink from all stakeholders about of what is expected from the sector and how this might most efficiently be delivered.

A stakeholder map of key players in the VET sector is provided in Appendix 3. Within this structure, the National Skills Standards Council (NSSC) is responsible for developing and maintaining national standards for VET regulation and for endorsing Industry Training Packages [18]. There are around 70 Industry Training Packages (ITPs). ITPs are the responsibility of the 11 Industry Skills Councils (ISCs). The ISCs involved in training and development of maintainers for heavy industry are Auto Skills, Construction and Property Services, Electrocomms and Energy Utilities (E-Oz), Innovation and Business, Manufacturing, Skills DMC (Drilling, Mining, Quarrying and Civil Infrastructure), and Transport and Logistics. Each ISC is recognised and funded by the Australian Government and governed by independent, industry-led boards. Some of this structure is also duplicated at the state level.

Since 2009, there has been a reform agenda which has reviewed many aspects of the Australian VET System. This continues today and its future is far from clear.

An ITP is the industry's specification of the skills and knowledge required to perform effectively in the workplace. It is a competency-based framework and is used to identify and assess the skills and knowledge people must demonstrate to work safely and effectively in the workplace. The ITPs provide learning and assessment materials but do not prescribe how an individual should be trained. Rather, ITPs provide competencies required for the tasks undertaken in the workplace and consist of units of competency, skill sets, assessment requirements and qualifications. Examples of training packages can be found in Appendix 4.

The role of designing and delivering training is done by Registered Training Organisations (RTOs). RTOs must be registered by the Australian Skills Quality Authority (ASQA); there are about 5000 RTOs in Australia [19]. Only RTOs can deliver nationally-recognised courses, accredited Australian Qualifications Framework (AQF) VET qualifications, and apply for Australian, state and territory funding.

As can be seen from the description above, the VET system is complicated to understand with numerous stakeholders and a high level of governance overhead involving federal, state and sector bodies. Conflicting stakeholder priorities and shifting political environments impact the VET system, and changes to the system must be passed through a hierarchy of administrative bodies. Consequently, the system appears reactionary, convoluted and bureaucratic, with unnecessary regulatory burden of red tape. The lag time between a proposed update to a competency and this being realised in RTOs has been identified as a significant shortcoming of the current system. By the time a change has been implemented, the new programs associated with the competency change are almost out of date.

> ***"Too often, training has been provider-led rather than industry-led" [1]***

Some sectors (mining in particular) have been very outspoken about their dissatisfaction with the VET sector. Two of their main concerns are that "Too often, training has been provider-led rather than industry-led" [1] and "When engaging with RTOs, the user is getting content and delivery models that are irrelevant to their needs. This irrelevant content calls into question the vocational education and training system's ability to meet the service provisions needed to provide a workforce capable of meeting the high supply and demand pressures of the industry [20]."

TRAINING APPROACHES FOR MAINTAINERS

The length of time required to train maintainers in Certificate III qualifications has come under criticism from some sectors. Currently, the rate of progression is contingent on both the apprentice's capability and the RTO's capacity to manage and provide training services which enable varied progression. Students are held to the same timetable of scheduled delivery and assessment, denying them the opportunity for progression despite having the skills and knowledge required to progress at an earlier stage. In today's world, with the help of education technology, this approach is one of missed opportunity. Treating a room full of individuals as a 'class' who move through a designated curriculum together represents an inefficient use of human capital at both extremes [17].

Some ISCs are working to realise the potential of Blended Learning (BL) techniques, which incorporate Information and Communications Technology (ICT) to support flexible and appropriate training. These techniques allow students in the same physical class to progress (while at different stages in their skill and knowledge development) and allow them to be assessed as and when they reach competence. For instance, the Energy Industry Apprentice Progression Management Systems (EIAPMS) pilot program is exploring options for flexible progression using BL techniques. However, the ability to make the most of these approaches is dependent upon the ability of RTOs to accommodate individual learning needs, rather than to treat the trainees as a homogenous group [17].

As mentioned, there is emerging interest in the concept of skill sets as an intermediate product of the formal VET system to manage supplementary training – paid for and organised by the employers. Skill sets prepare individuals to perform a specific job function, and can be used for multi-technical skilling purposes to keep pace with evolving skill requirements [21]. Ideally, skill sets could both form the basis of full qualifications, and also function as responsive "skill top-ups" for the already qualified. This facilitates labour mobility, allowing individuals to transfer between job roles and even occupations.

One of the reasons for interest in skills sets is that VET qualifications required for the skill base of tomorrow tend to be slow to evolve. There is also concern that full qualifications may be too broad – resulting in over-skilling and the unnecessary allocation of time and resources to the development of skills that may not be needed or applied in the context of the specific job role [21]. In this sense, full qualifications are not always needed or fit for purpose. The vital next step for the skill sets approach – which offers the technician units of learning that are concise and immediately useful to their employer – is to develop a mechanism to package skill sets into a nationally-recognised and portable qualification.

DEFINING MAINTAINER COMPETENCES

Thanks to industry support, the authors have been able to view examples of competence capture systems from a wide range of organisations. Below are some general comments.

- There is little that is common about the wording, structure, or content of maintainer competence capture systems between organisations, even those working in the same sectors.
- There is no consistent use of the terms for skills, qualifications and competences.

- All organisations have sections for technical competences, only a few have sections for assessment of behaviours, also described as soft-skills.
- There was very little in common about the wording of the technical competence sections. Some organisations list the competence in terms of the title of the training completed, while others focussing on describing the activity that needed to be performed.
- In some organisations, tracking is done at the individual asset class level (e.g. pumps) or at the area level, whereas others are at a higher, more general level.
- A few organisations have developed simple but useful matrices for technical skills with different levels of tasks that maintainers should be able to do on one axis and their ability to perform at those levels on the other.

In summary, there is an opportunity to develop a common approach across organisations that work in the same asset sectors (both operators and contractors) to define technical and behavioural competences for maintainers. These competences should be developed with a view to the roles maintainers will have in the future, rather than be wedded to the ideas of the past. National consistency is key to avoiding duplication of regulatory requirements. Once such frameworks are set, ideas such as a 'skills passport' can be explored.

ASSURANCE OF COMPETENCE

A number of industry insiders talked about the issue of assurance (verification) of competence. By this they mean: how do you know that the technician can perform the tasks that appear on their training record? When were they trained? What was the quality of that training? Have they retained the skills they learned? Will they demonstrate appropriate behaviours?

Insight into actual practices (and the effects of poor training and skills) is often only gained from boards of inquiry [22] and investigations conducted after accidents [23-26]. Very limited work has been done looking at how maintainers work [27, 28] or the role of organisational culture on maintenance practices [29, 30]. Of particular concern is the lack of research to understand how maintainers acquire and build technical skills, conceptual knowledge e and cognitive skills. Oedewald and Reiman [31] is one of the few studies to look at conceptual

> ***"We don't know the poor performers until they perform badly"***

knowledge development. Most of the work around maintainer training has been directed at exploring training and experience as contributors to maintenance errors [32] and safety [33], and not to the efficacy and appropriateness of training for day-to-day work. Given the amount of both government and organisation funding spent on training, this lack understanding of the efficacy of training approaches and their transfer to competencies displayed in the workplace is a major oversight.

Running assurance programs requires competent staff to verbally verify understanding of the process or to observe maintainers performing tasks. Once complete, the verification records have to be generated and stored. Doing this for one's own employees is one thing, doing it for a contractor coming onto site is quite another and the requirement to do this has the potential to add costs and time to contractor deployment. There are already businesses which provide a service to collate qualifications and ensure that maintainers arriving on site have the right pieces of paper, but a qualification is not the same as an assured competence. Various initiatives around assurance are being looked at but these tend to be organisation-specific, and the authors are not aware of any mining sector-wide coordinated work in this area. There is considerable opportunity in this space for a more coordinated effort within the mining industry and across other resource-related sectors to establish a one-stop shop for assurance recording and tracking.

DISCUSSION

KEY THEMES

There is a pervasive sense of changes afoot in maintenance, driven by technical developments in automation, telecommunications and information technologies, as well as business drivers – especially safety. These technologies will change the nature of much of maintainers' work and require the development of new skill sets [9, 34, 35].

When interviewed, one industry contact summarised these advances in technology, and the consequent skills shortage: *"Vendors of mechanical equipment are increasingly relying on electronic add-ons, often with embedded computing capabilities, to differentiate their products and gain market advantage. Unfortunately, traditionally trained technicians often do not have the skills to install these components correctly and/or troubleshoot any issues arising from poor installation, electronics failure or cross-device interference. This lack of skills in some industries is restricting the uptake of these potentially hugely beneficial electronic add-ons."*

> ***"This lack of skills in some industries is restricting the uptake of these potentially hugely beneficial electronic add-ons"***

New skills required for all technicians will include basic control systems, electrical engineering and computing competencies. Skills such as interpreting fault messages, data fusion and data extraction represent a relatively new and specialised strand of abilities that are already being sought after. Advances in mobile devices and augmented reality will involve technicians needing to be trained in how to navigate and troubleshoot the various user interfaces, but may also lead to a lower skill class for basic maintenance procedures. The rise of modular component design will give rise to a change-out approach, with a plug-and--play mentality.

Despite changes to required skill areas and skill levels, maintainers are still essential in the resource industry. However, we expect to see more use of robotics in assisting with high hazard repairs. This will require maintainers to operate (and repair) equipment that is itself repairing equipment. Examples of this include robotic liner handlers for grinding mills and tyre-changers for haul trucks.

As this range of required competences increases, there comes a time where we need to consider that this range is beyond the scope of any one maintainer and we should consider splitting the maintainer role into a number of different roles. Each role will have its own competences, culture and behaviours appropriate to the nature of the role.

With regard to training, the presently overly-bureaucratic nature of Australia's VET sector has resulted in the emergence of an unaccredited 'skills sets' approach to workforce training, particularly in the mining industry. The authors support this form of training for its ability to deliver skills that are current, concise, immediately useful and convenient to attain. However, in order to facilitate the mobility of these skills – an essential feature for the wider mining industry – sector-wide and nationally-consistent competency assessment and assurance frameworks must be developed. The resulting 'skills passport' would represent a nationally-accredited and portable portfolio of competencies, allowing workers safe passage to move between job roles and organisations.

MAINTAINER OF THE FUTURE – DEFINING NEW ROLES

This White Paper supports the development of different roles within maintenance groups which focus more directly on the nature of the work, rather than on what is being done. Using an analogy from the medical profession, this could look like the following:

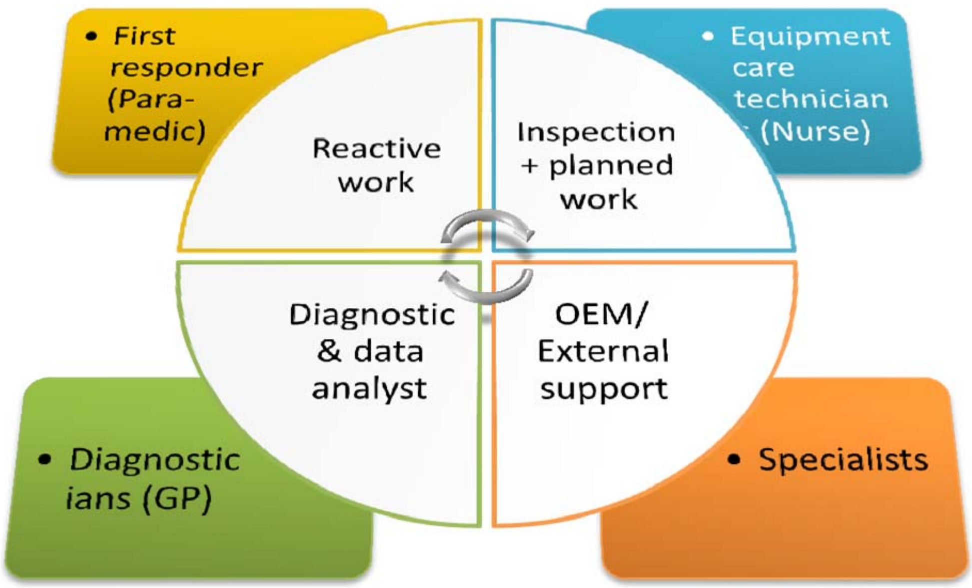


Figure 2: Maintainer of the Future – new roles

In Figure 2, four different roles for maintainers are defined; each has equivalence to a role in the health sector.

- First responder (Paramedics) – front line, plug-and-play, reactive work
- Equipment Care technician (Nurse) – roving position, focus on inspections and preventative/ proactive work (IT enabled with augmented reality and real-time support)
- Diagnostician and data analyst (GP) – Primarily office-based performing the diagnostics and inputs to planning (supports the above 2 streams)
- Specialists (Specialist health support) – Subject matter expert and/or specialist repairer

This arrangement would allow maintainers to develop skill sets in different areas such as a) diagnostics, b) preventative and proactive work, c) reactive and minor repair work, and d) fabrication and specialist repairs. Each of these areas has quite distinct skills sets and behaviours associated with them, and require different types of the support from the maintenance management system. Maintainers trained in diagnostics could make full use of the emerging technologies and embedded sensors. They would be involved in providing the information necessary to support the role of maintainers involved in proactive and preventative work. Maintainers involved in reactive and minor repairs would likely see their day-to-day work little changed from at present, but would likely need to have a broad range of skills across the mechanical, electrical and IT spectrum, and may benefit from uptake of support tools such as augmented reality.

With the tightening job market for graduate engineers, it is plausible that a mutually beneficial solution may be to introduce engineers into the diagnostician role. For this to occur, the apparent Australian social stigma of engineers working on-site and not in an office may have to be erased. The transforming and less physical nature of work now being performed on mine sites may help facilitate this change in perception.

Why would this separation of the maintainer into these four roles assist in adapting to a new order in which embedded sensors, modular designs, autonomous equipment and new methods of technical support are available? The separation allows for each role to develop relevant skills for the role which depend on both the inherent ability and interests of the maintainer, and also the technical requirements of the role. Some people are skilled in doing hands-on repair work and work well in a less structured environment. Others have the educational background and interest to manage diagnostic work. This separation allows for a better fit to the distinct roles which will also support more focussed training. In this paradigm, maintenance work is assigned to maintainers with relevant skills rather than their traditional craft [7].

FINALLY

There are many barriers that stand in the way of Australian business (and the mining industry in particular) being able to take advantage of technical and business developments that could reshape the way in which maintenance is delivered. Change will need a support of the entire sector, involving OEMs, asset owners, maintenance contractors, the training sector and government. Only limited progress will be made unless all players in the supply chain are involved. Individual organisations can manage this on a project-by-project basis, but it is difficult to up-scale. Each group in this supply chain could take steps that will make a wider-scale adoption of new technologies and processes possible, and examples are covered in this paper. The big question is, will they?

However, change is difficult. We are reminded of this when we re-read articles, such as the following extract from Harvard Business Review in 1967 *"Gazing into a crystal ball, we would see, I suspect, completely standardized equipment and greatly improved maintenance procedures in the years ahead. For example, equipment will be designed for its production ability and maintainability. There will be free access to all parts and components, and machine life will be longer than is now the case. Economy of repair, or elimination of maintenance, will become a key feature of design. Equipment will be standardized to a point where complete transferability from machine to machine and plant to plant will be achieved. Also in the offing are many more quick change and economically replaceable units [36]".*

In 1998, the "Mine of the Year 2020" paper identified many of the technical developments we are now seeing emerge. However progress towards these developments has been slow. This is especially frustrating considering that the technical platforms to support these have been around for over 20 years [3].

Why has sparking change to maintenance practices in the mining industry been so difficult? There are many views on this. They include:

- Few executives in the mining sector have direct management experience in maintenance.
- Changes to maintenance groups usually focus on cutting costs rather than improving competency, quality and efficiency.
- Managers focus on quantity rather than the quality of maintenance work. Poor quality work generates more maintenance work.

- Good maintainers are craftsman, they need support. This is not appreciated by managers who have not seen the difference between good and poor maintenance work.
- Historically there has been a lack of meaningful and trusted performance measures for maintenance, so measuring improvements is difficult.
- The effect of poor maintenance management on production is hidden due to a having a surplus of mobile equipment that can be redeployed or circuit redundancy.
- Changes in maintenance management behaviours require similar changes in production, engineering and purchasing. Organisationally this change cuts across different silos with the changes in production behaviours being most challenging to achieve.

It was evident from the interviews and workshop that there is certainly no shortage of maintenance professionals who are passionate about improving how maintenance is performed, and the capability of the maintainers who do it. The technology platforms to support these changes are, in many cases, already in place. What is needed is leadership within companies and by industry-representative bodies to move forward.

The four roles defined for the maintainer of the future in this paper represent a fresh philosophy to enable a transformation in how we perceive the work that maintainers perform, and what competent and motivated maintainers could deliver to the businesses they work for.

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ABOUT THE AUTHORS

Professor Melinda Hodkiewicz sits on the ISO (International Standards Organisation) committee for the new Asset Management Standard ISO 55000 and chairs the associated Standards Australia committee.

After working for a decade in operations and maintenance roles in the mining industry, Melinda completed a PhD in performance and condition-monitoring and joined the academic staff at UWA. She retains close contact with her industry roots. In 2011 she was a finalist in the CME (Chamber of Minerals and Energy) Outstanding Women in Resources award and in 2012 won the UWA Safety Leadership Award. She has published widely on technical and management issues relevant to the mining and other heavy industry sectors.

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APPENDICES

APPENDIX 1: NUMBER, SECTORS AND DEMOGRAPHICS FOR MAINTAINERS

Australian Bureau of Statistics Census data was used to collate information on the number of people in selected trades and sectors. Maintainers are classified under a number of codes by the Australian Bureau of Statistics. There are 1.42 million people who classified themselves as Technicians and Trades Workers in the 2011 Census. As shown in Table 4, the main sector for employment is Construction (412,896) followed by Manufacturing (236,825) and Other Services (176,511). Mining (41,973), Electricity, Gas, Water and Waste Services (28,553) and Transport, Postal and Warehousing (25,577) have smaller numbers assigned to them directly [4]. There is no class in the ABS data for contractors that work across multiple sectors and this may account for the large numbers in the Other Services category. A comparison with the data from 2006 is also provided in Table 4. This shows there has been a 60% increase in technicians in the mining sector compared to the 9% increase in industry in general.

Table 4: Percentages of Technicians and Trades Workers by sector (Source: Australian Bureau of Statistics 2006 and 2011 Census)

	2006		2011	
Industry	Technicians and Trades Workers	% Total	Technicians and Trades Workers	% Total
Agriculture, Forestry and Fishing	15,111	1.2	12,997	0.9
Mining	26,183	2.0	41,973	2.9
Manufacturing	249,747	19.1	236,824	16.6
Electricity, Gas, Water and Waste Services	23,215	1.8	28,553	2.0
Construction	354,099	27.0	412,896	29.0
Wholesale Trade	31,993	2.4	32,558	2.3
Retail Trade	72,386	5.5	66,104	4.6
Accommodation and Food Services	74,061	5.7	91,546	6.4
Transport, Postal and Warehousing	22,400	1.7	25,577	1.8
Information Media and Telecommunications	30,325	2.3	26,892	1.9
Financial and Insurance Services	4786	0.4	5161	0.4
Rental, Hiring and Real Estate Services	5616	0.4	6704	0.5
Professional, Scientific and Technical Services	57,674	4.4	69,891	4.9
Administrative and Support Services	26,964	2.1	29,914	2.1

Public Administration and Safety	47,475	3.6	47,932	3.4
Education and Training	24,170	1.8	26,204	1.8
Health Care and Social Assistance	38,401	2.9	42,493	3.0
Arts and Recreation Services	14,019	1.1	15,777	1.1
Other Services	158,161	12.1	176,511	12.4
Inadequately described	21,078	1.6	18,294	1.3
Not stated	11,392	0.9	10,345	0.7
Total	1,309,256	-	1,425,146	-

Table 5 shows the distribution of employees classified as trades and technicians by the ABS by sector and against other employee classifications. This shows that 41,973 (27%) of employees designated as working in the mining sector are classified as technicians and trades workers. Within this group, the main sub-groups in mining are Metal Fitters and Machinists (14,574), Electricians (5505), Structural Steel and Welding Trades (3135) and Other Building and Engineering Technicians (8372).

Table 5: Distribution of workers classified as tradesmen and technicians (Australian Bureau of Statistics 2011 Census)

	Technicians/ Trades	**Managers**	**Professionals**	**Labourers**	**Operators**	**Total**
Mining	27%	11%	20%	6%	38%	156,796
Manufacturing	32%	17%	11%	22%	18%	736,313
Electricity, Gas, Water, Waste	33%	17%	24%	10%	17%	87,772
Construction	57%	13%	5%	17%	9%	724,204
Other Sectors	14%	17%	52%	8%	8%	3,189,804
Total	1,177,389	789,832	1,830,126	561,333	536,209	4,894,889

There is little literature to draw on that looks at what is an acceptable size for the pool of tradesmen necessary to support the mining or other industries. We know that there are cycles and fluctuations, with the labour market for technicians and trades workers expanding rapidly in the period to 2008, followed by a marked easing during the global financial crisis. From late 2009 though, there were signs of increased demand for technicians and trades workers, and the labour market continued to tighten over the course of 2010 [37]. One of the areas of sustained growth is for electro-technology and telecommunications trades, with numbers rising by 9.1 per cent (20,600 people) over the year to February 2011 to 245,300 [37]. This is to be expected, given the increased use of sensors, integrated devices, and digital technologies for equipment and communications, as described in body of this report.

Table 6 shows ABS data on demographic data on technicians and trades workers. This shows that largest demographic group in the mining sector is the 30-39 year age group. In the manufacturing and electricity, gas and water sectors it is the 40-49 year age group.

Table 6: Demographic of technicians in selected sectors (Australian Bureau of Statistic 2011 census)

Sector	Occupation	10-19 years	20-29 years	30-39 years	40-49 years	50-59 years	60-69 years	Total
Mining	Operators	1	21	28	27	19	5	58,932
	Professionals	0	27	32	23	14	4	30,703
	Managers	0	6	26	35	24	7	16,525
	Technicians/ Trades	3	23	28	25	17	4	41,970
Electricity, Gas, Water, Waste	Technicians/ Trades	3	21	22	25	22	7	28,553
Manufacturing	Technicians/ Trades	6	22	22	24	18	7	23,6684

Further analysis using ABS 2011 Census filtered by 'Industry of Employment' found that 85.3% of workers in the mining industry are full-time, with around 8.3% being employed but away from work, and 6.4% being part-time. For full-time employment, a retrieval of age by sector in one year increments showed that the average age in the mining industry (39.6 years) is in fact lower than the average across all sectors of 40.7 years, as shown in Figure 3. This challenges the view, sometimes heard, that the mining sector has an aging workforce, and should be preparing for a bow-wave of experienced maintainers retiring in the next 5-10 years.

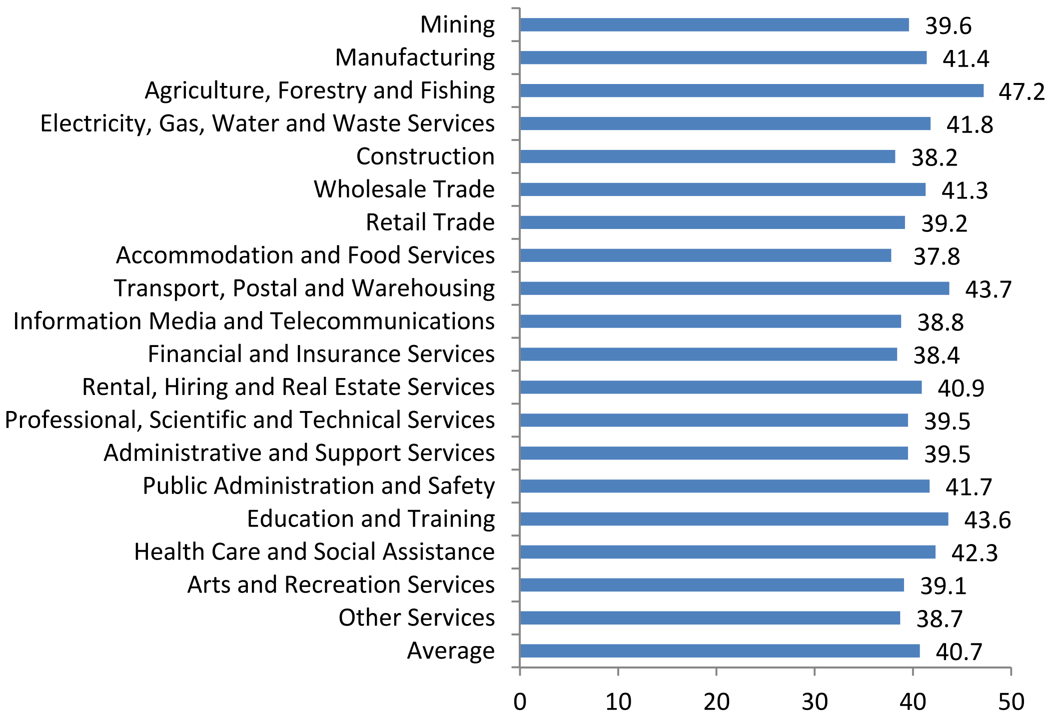


Figure 3: Average age in years by sector (Australian Bureau of Statistics 2011 Census)

Table 7 shows the number of people graduating in 2011 from Industry Skills Councils responsible for training the next generation of operation and technical personnel. These are shown below based on data from the VOCSTATS system available through NCVER (National Centre for Vocational Education Research). These numbers are for all qualifications not just maintenance related.

Table 7: Number of apprentice and trainee completions in 2013 from selected Industry Skills Councils [38]

Industry Skills Councils	Apprentice and trainee completions July 2012-2013
Auto Skills Australia	8836
Construction and Property Services	18371
E-Oz Energy	8357
Manufacturing	26177
Skills DMC	6017
Transport and Logistics	16016

APPENDIX 2: **ENGINEERING GRADUATE DATA**

Figure 4 was generated through data obtained from the *GradStats* reports produced by GCA (Graduate Careers Australia) [39] . It depicts the percentage of engineering graduates by discipline who were still seeking full-time work 4 months after graduation. A general increasing trend in job-seeking graduates is noted, as well as significant increases across all disciplines apart from Computing and Mining Engineering between 2012-2013. Data was not yet available for the 2014 graduates, though it is expected that a significant increase in job-seekers will be demonstrated.

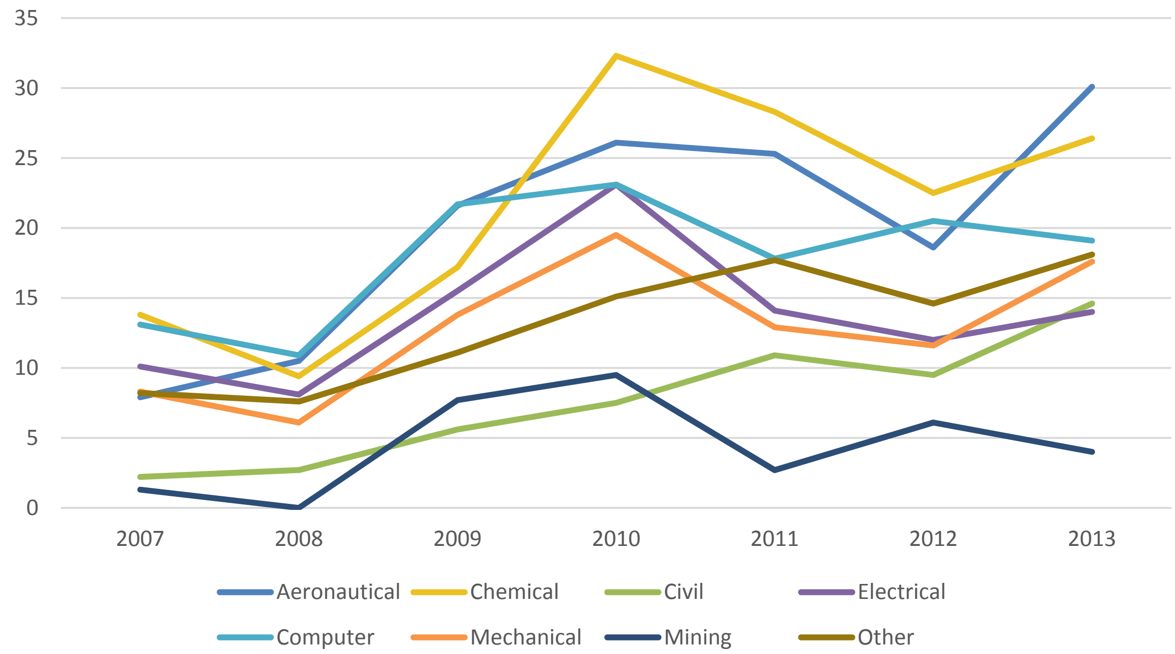
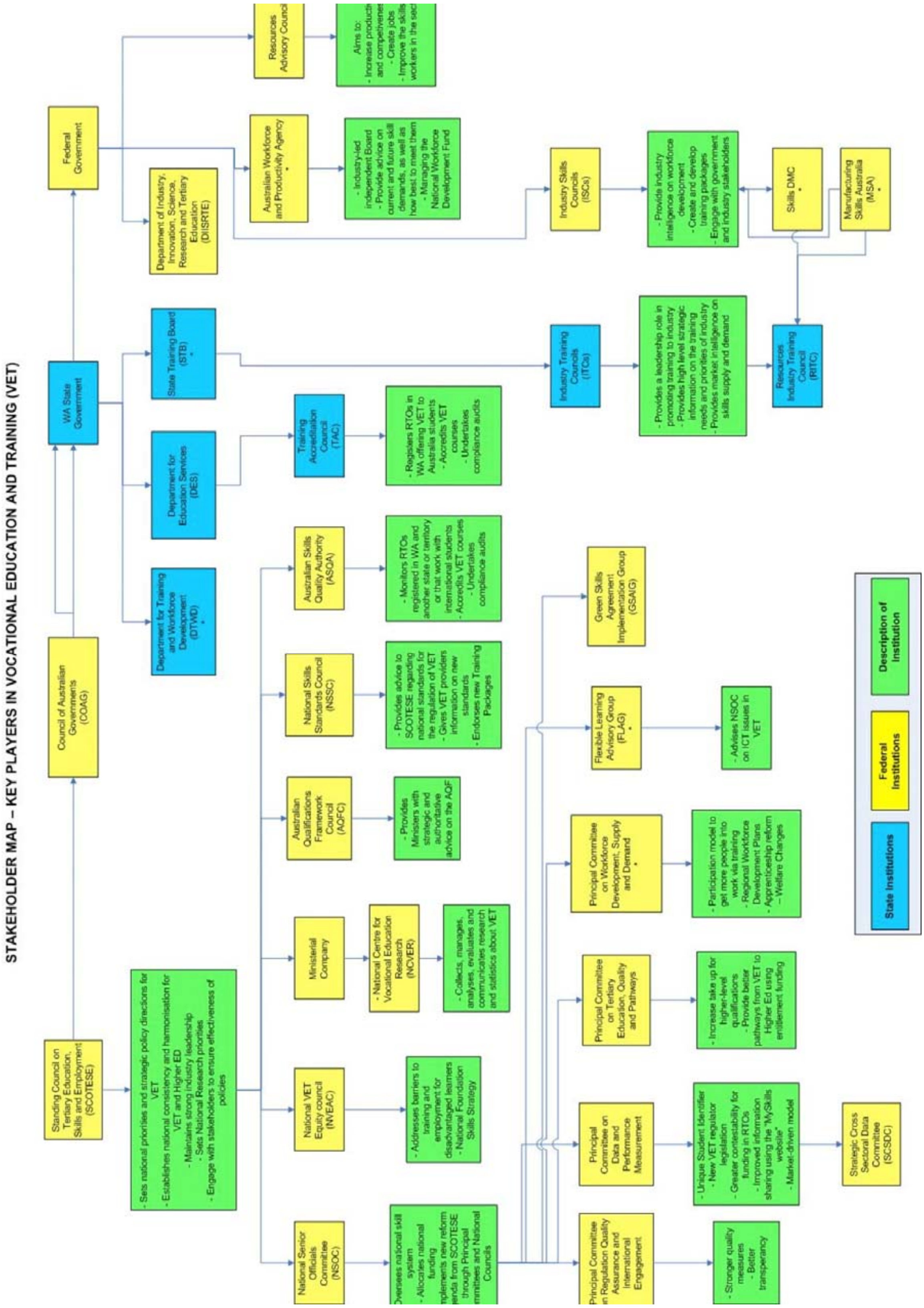


Figure 4: Percentage of engineering graduates by discipline seeking full-time work 4 months after graduation

APPENDIX 3: **VET SYSTEM STAKEHOLDER MAP [21]**



APPENDIX 4: CERT III AND IV PACKAGES RELEVANT FOR MAINTAINERS IN HEAVY INDUSTRY AND THE INDUSTRY SKILLS COUNCIL RESPONSIBLE

Table 8: Listing of Certificate III qualifications by training package and Industry Skills Council

ISC	Training Package	Cert III
Manufacturing Industry Skills Council	Metal and Engineering	Engineering – Electrical/ Electronic Trade (MEM30405) Engineering – Mechanical Trade (MEM30205) Engineering – Fabrication Trade (MEM30305) Engineering – Technical (MEM30505) Engineering – Production Systems (MEM30105)
Manufacturing Industry Skills Council	Manufacturing	Process Manufacturing (MSA30107) Manufacturing Technology (MSA30208) Surface Preparation and Coating Application
	Chemical, Hydrocarbons and Oil Refinery	Process Plant Operations (PMA30113)
Electrocomms and Energy Utilities	Electro-technology	Electrical Fitting (UEE33011) Electrical Machine Repair (UEE30606) Electronics and Communications (UEE30911) Electro-technology Electrician (UEE30811) Instrumentation and Control (UEE31211) Rail Communications and Networks (UEE31511) Renewable Energy (UEE32011) Switchgear and Control Gear (UEE30711)
	Generation	Operations (UEP30212) System Operations (UEP30112)
	Transmission, Distribution and Rail Sector	Power systems – distribution cable jointing (UET30812) Power systems – distribution overhead (UET30612) Power systems – rail traction (UET30712) Power systems – transmission overhead (UET30512)
Transport and Logistics Industry Skills Council	Transport and Logistics	Mechanical Rail Signalling (TLI31913) Rail Infrastructure (TLI32511) Rail Signalling (TLI32611) Rail Structures (TLI32111) Mobile Crane Operations (TLI31710)
Skills DMC	Resource and Infrastructure	Resource Processing (RII30413) Underground coal operations (RII30213) Underground metalliferous mining (RII30313) Well servicing operations (RII32213)
Auto Skills Australia	Automotive Industry Retail, Service and Repair	Mobile Plant Technology (AUR31212) Automotive Diesel Engine Technology (AUR31512) Automotive Diesel Fuel Technology (AUR31412) Automotive Drive Train Technology (AUR31612) Light Vehicle Mechanical Technology (AUR30612) Automotive Electrical Technology (AUR30312) Automotive Engine Reconditioning (AUR31312) Automotive Tyre Management (AUR32613) Automotive Underbody Technology (AUR32512) Heavy Commercial Vehicle Mechanical Technology (AUR31112) Mobile Plant Technology (AUR31212)
Innovation and Business Industry	Information and Communications Technology	Information, Digital Media and Technology (ICA3011)
	Telecommunications	Telecommunications (ICT30213) Telecommunications cabling (ICT30313) Telecommunications Digital reception technology (ICT30413) Telecommunications Fixed Wireless Installation (ICT30813) Telecommunications Cabling (ICT30313)

Table 9: Listing of Certificate IV qualifications by training package and Industry Skills Council

ISC	Training Package	Cert IV
Manufacturing Industry Skills Council	Metal and Engineering	Engineering MEM40105
	Manufacturing	Process Manufacturing MSA40311
	Chemical, Hydrocarbons and Refining	Process Plant Technology PMA40113
Electrocomms and Energy Utilities	Electro-technology	Electrical – Instrumentation UEE40411 Electrical Equipment and Systems UEE43011 Electronics and Communications UEE40711 Electro-technology – Systems Electrician UEE40611 Industrial Automation and Control UEE43211 Industrial Electronics and Control UEE40911 Hazardous Areas Electrical UEE42611 Installation inspection and Audits UEE40311 Electrical – Rail signalling UEE41211 Rail – Communications and Network Systems UEE41711 Refrigeration and Air Conditioning Systems UEE41306
	Generation	ESI – Generation Operations UEP40212 ESI – Generation Systems Operations UEP40112
	Transmission, Distribution and Rail Sector	ESI – Network Systems UET40412 ESI – Power Systems Network Infrastructure UET40612 ESI – Power Systems Substations UET40512
Transport and Logistics Industry Skills Council	Transport and Logistics	Materiel Logistics TLI41510 Mobile Crane Operations TLI41910 Rail infrastructure TLI42311 Rail Network Control TLI42211 Rail Safety Management TLI42413
Skills DMC	Resource and Infrastructure	Metalliferous Mining Operations Underground RII40313 Resource Processing RII40513 Surface Coal Mining (Open Cut examiner) RII40213 Surface Extraction Operations RII40113 Underground Coal Operations RII40413
Auto Skills Australia	Automotive Industry Retail, Service and Repair	Automotive Electrical Technology AUR40612 Automotive Management AUR40112 Automotive Mechanical Diagnosis AUR40212 Automotive Mechanical Overhauling AUR40812
Innovation and Business Industry	Information and Communications Technology	Systems Analysis and Design ICA40711 Information Technology ICA40111 Information Technology Networking ICA40411 Information Technology Support ICA40211 Information Technology Testing ICA40611 Web based Technologies ICA40311
	Telecommunications	Telecommunications Network Design ICT40713 Telecommunications Network Engineering ICT40210 Telecommunications Network Planning ICT40510 Telecommunications Networks Technology ICT40613 Telecommunications Radio Communications ICT40313