Manufacturing Skills Australia

Manufacturing in 2030
– the new horizon

Symposium Stimulus

INDUSTRY SKILLS COUNCILS
Creating Australia's Future

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Welcome from the Chair

If we had a crystal ball it would be easy to know what actions today would ensure our industries are equipped to thrive 20 or 30 years from now. We could confidently focus our energy and resources, develop the required workforce skills and knowledge and streamline our investments. Clever though we humans are, we haven't yet manifested crystal ball technology. Instead we must rely on our capacities for visioning the possibilities, analyzing what we do know, exploring what we don't, and sifting for the gold. It is the excitement of gold that drives us to make plans and take action.

MSA has initiated this symposium in a quest for gold. With a focus on manufacturing, this event brings together some of Australia's best minds and visionaries to explore where manufacturing could be in 2030 and beyond. How might manufacturing look in the near and far future? What jobs will it offer and what skills and attributes will they need? As the key agency assigned to collect industry intelligence on manufacturing skill needs and direct workforce development, MSA is looking beyond the present experience of manufacturing to help set a course for its strategic reinvigoration.

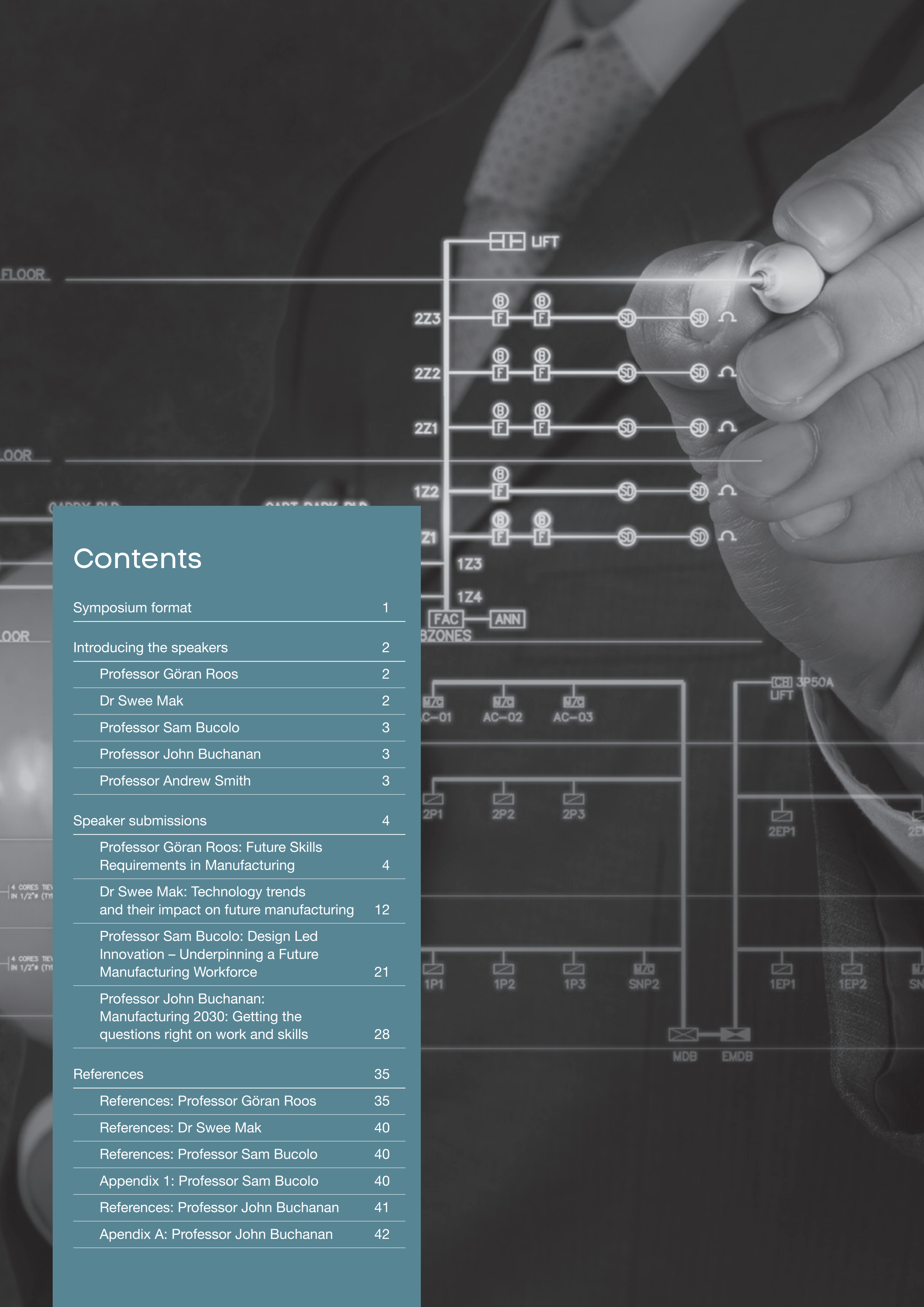
The public conversation about manufacturing today tends to focus on its demise – particularly of mass manufacturing operations - and the many thousands of jobs that have been lost. Manufacturing has certainly been in transition in recent years and it is clear that old models cannot effectively navigate today's challenging and highly competitive global conditions. MSA and its manufacturing stakeholders want to talk about the opportunities that are emerging and how Australia can secure a strong, global position in the future.

MSA is looking beyond the present experience of manufacturing to help set a course for its strategic reinvigoration.

The future of manufacturing will look quite different to its past, and while reflections are helpful when making projections, they cannot fully anticipate the implications of the wave of change that is occurring. Manufacturing is facing new developments in technology, information management and business practice, which will totally disrupt our projections and challenge our expectations. We are approaching a new horizon in manufacturing, a journey that can be likened to that of explorers who ventured into unknown lands.

MSA welcomes you to its 2014 symposium: Manufacturing in 2030 – the new horizon. We hope you find it an exciting stimulus for thinking and planning the future of manufacturing.

Megan Lilly
Chair, Manufacturing Skills Australia.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1P1
1P2
1P3
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1EP2
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Contents

Symposium format

MSA is delighted to bring together some of Australia's great minds to focus on key themes and considerations that are emerging for manufacturing, and what the implications are for workforce skills.

The Symposium will explore some of the context and drivers for this focus and highlight current industry perspectives and policy influences. It will examine some of the findings in recent research conducted by both MSA and the Australian Workforce and Productivity Agency (AWPA). It will then delve into the unique perspectives of its four guest speakers.

Each speaker has prepared a 'think piece' on Manufacturing in 2030, which will be the focus of their presentation. These pieces are included in this paper for reference and consideration. Participants will be invited to contribute to the exploration during Q&A sessions. The event will be recorded and materials made available via the MSA website.

Guiding the events will be an MC with extraordinary passion for exploration, Dr Karl Kruszelnicki. Dr Karl has shared his love of science and enquiry to audiences via books, newspapers, magazines, radio, TV and the internet. He has degrees in Physics and Maths, Biomedical Engineering, Medicine and Surgery and has worked as a physicist, tutor, film-maker, car mechanic, labourer, and as a medical doctor at the Kids' Hospital in Sydney.

A creative and inspiring visionary, Dr Karl is truly (and actually) one of Australia's National Living Treasures, and MSA is confident that he will help set the tone for this gathering of minds.

The Symposium is just the beginning. MSA will produce a summary publication that captures key discussion points made during the event and respond to these with recommendations for action. These recommendations will be used to direct MSA's work activity and influence policy development.

MSA is strongly committed to drive a focus on developing a healthy and sustainable manufacturing industry.

There are no old roads to new directions.

[The Boston Consulting Group]

Introducing the speakers

Professor Göran Roos

Since his tenure as Adelaide Thinker in Residence (2010-11) for the Government of South Australia, Professor Roos has brought a heightened focus on the significant and multiplied value of manufacturing across the Australian economy. He has called for a new paradigm that will lead manufacturing into a future that is innovative, dynamic and globally competitive. The opportunities for Australian manufacturing he claims are extensive and available, and these need to be promoted, championed and systematically pursued.

A self-proclaimed 'techno-optimist', Professor Roos has been associated with innovative thinking and strategic development throughout his career. He has contributed on numerous boards and think tanks, provided consulting advice to public and private clients across 40 countries, and is an award-winning author, with over one hundred books, chapters and articles to his name.

Professor Roos is recognised as one of the most influential thinkers of the 21st Century, with particular expertise in strategy, research & development, national and regional innovation systems issues, knowledge management and intellectual capital. He brings extensive insight and expertise to explore what brave policy decisions are needed for Australian manufacturing to prosper.

For this Symposium, Professor Roos reviews the current literature to assess the pressures on productivity, the changing structure of manufacturing and the continuously increasing pace of technology development. He illustrates that the skills required in manufacturing tomorrow will be very different from those of today. This will have implications for the level of education required, the management of continual skills development, as well as the range of skills needed to capitalise on growing trends such as servitization.

Dr Swee Mak

As the Director of CSIRO's Future Manufacturing Flagship, Dr Mak is one of Australia's most significant champions in the development and application of resource efficient, clean and transformative technologies that will help to actualise Australia's ambitions for low carbon and sustainable industries. His scientific, strategic and commercial leadership covers an extensive portfolio that aims to increase the productivity, competitiveness and sustainability of Australian manufacturing.

Dr Mak is responsible for determining and managing research priorities for the Flagship, which include the development of enabling technologies and processes, and sustainable, high performance materials for application across the manufacturing sectors. He has extensive experience in innovation management, commercialisation and the transfer of technology to industry and has witnessed first hand the incremental and transformational impacts of technology on manufacturing operations.

In his work Dr Mak also establishes and manages Australian and international partnerships and collaboration across industry, government and academia. He has authored over 50 scientific and technical papers and provided expert advice and R&D services to over 30 companies in Australia and overseas.

Dr Mak will explore the trend toward mass customisation and greater customer control in design and production processes, and the implications for manufacturers. He will discuss how new technologies such as additive manufacturing, assistive automation and flexible scalable intelligent processing, combined with customer-centric design and agile business systems, will enable firms to effectively compete in today's global market.

Our future will be shaped by the assumptions we make about who we are and what we can be.

[ROSABETH MOSS KANTER, America the Principled]

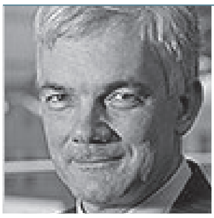
Professor Sam Bucolo

Professor Bucolo is a pioneer in the emerging field of design led innovation. As Professor of Design and Innovation at the University of Technology Sydney, he leads investigations into the value of design led innovation to the growth and productivity of businesses and the Australian economy.

His work has added significant understanding of the relationship of design led innovation to business strategy and organisation value. He advocates for breaking down barriers between designers and non-designers and embedding design capability throughout the organisation to drive innovation, problem solving and business development. Professor Bucolo stresses that businesses that adopt this new way of thinking can not only respond more effectively to technological and market changes, but also tap into unpredicted opportunities. Design led innovation he claims, can transform business operations and create a significant point of difference in their product offering.

Professor Bucolo has 25 years' experience working within academia, start up's, SME's and the corporate sector and has consulted widely to industry, spanning the medical devices, consumer products, telecommunications, automotive and mining services sectors. He is also the convenor of the recently established Australian Design Integration Network and is an executive board member of the Cumulus global network. He was previously Professor and Chair in Design and Innovation at the Queensland University of Technology.

Professor Buculo's discussion will stimulate thinking around the role and value of design led innovation and why manufacturing needs to embrace design as a mandatory skillset for its future workforce.



Professor John Buchanan

Professor Buchanan is one of Australia's key researchers in labour market conditions and employment, and contributes widely to debate on Australia's policy development in these areas. He was part of the team that undertook the first Australian Workplace Industrial Relations Survey (AWIRS) and is widely published with several books, and dozens of research reports, articles and conference papers.

Professor Buchanan is currently Network Leader for the University of Sydney's Health and Work Research Network - a consortium involving experts from the Business School, Medical, Health Sciences and four other faculties. He has extensive expertise in the changing nature of work and implications for both workers and employers, and today devotes special attention to the evolution of the labour contract, working life transitions and the dynamics of workforce development.

In his presentation Professor Buchanan proposes that the future of manufacturing will depend on better management of the flows of labour to ensure skill availability, as well as developing capacity to adapt to changing circumstances. He explains that everyone within the manufacturing workforce will need to contribute to building the adaptive capacity of enterprises to ensure they are able to capitalise on opportunities as they emerge.

Professor Andrew Smith

Professor Andrew Smith is Professor of Management and Deputy Vice-Chancellor (Academic) at Federation University in Victoria (previously known as the University of Ballarat). An acknowledged international expert in employer training policy, Professor Smith is a well-known researcher in vocational education and has conducted extensive research in the area of employer training strategies and the development of national vocational education and training policy. He has worked with senior policy makers in VET at national and state level and served on numerous national committees in vocational training.

Professor Smith will bring his art of analysis to provide a summary of the key points made by the Symposium speakers.

Speaker submissions

The following 'think pieces' have been provided by the guest speakers to explore key themes and considerations for the Symposium's enquiry:

'Where could manufacturing be in 2030, and what skills might we need?'

Prof. Göran Roos, Chair, Advanced Manufacturing Council, Adelaide

Professor Göran Roos : Future Skills Requirements in Manufacturing[1]

Abstract

As manufacturing itself is changing so too are the skills requirements. This is primarily driven by changing structure and technology.

This paper reviews the literature relating to the skills consequences of the pressures on productivity, the changing structure of manufacturing and the continuously increasing pace of technology development.

The conclusion is that the skills requirement in tomorrow's manufacturing will be very different from that of today.

Productivity Pressures

Total Factor Productivity (TFP) measures the changes in output per unit of combined inputs. A change in TFP reflects the change in output that cannot be accounted for by the change in combined inputs, thus TFP measures reflect the joint effects of factors like new technologies, economies of scale, managerial skill, changes in the organisation of production, changes in capital services, changes in labour services, changes in energy use, changes in materials, changes in purchased services, etc. TFP is often seen as the real driver of growth within an economy:

- The biggest factor in increasing economic growth and improving living standards is the economy's ability to continuously produce more out of less, also known as productivity (Fox, 2002).
- Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per employee (Krugman, 1990).

There are many drivers of productivity on the firm level but from a skills perspective the most relevant are:

Managerial competence and capability together with managerial practices[3]

The seminal studies by Bloom et al. find a statistically strong correlation between a firm's management practice score (see figure 1) and the firm's TFP. The economic impact of moving between quartiles of management practice score varies between 3.3% and 7.5% which is equal to between a third and a quarter of the corresponding TFP. Bloom et al. (2013b) estimate that management could account for on average 29% of a country's TFP deficit.

[1] This paper is built on Roos, G. (2014). Manufacturing in a High Cost Environment – Basis for success on the firm level. Chapter 13 in Roos. G. & Kennedy, N. (2014). Succeeding in a High Cost Operating Environment. IGI Global. In Press. and Roos, G. (2014). Manufacturing in a High Cost Environment – Basis for Future Success on the National Level. Chapter 1 in Roos. G. & Kennedy, N. (2014). Succeeding in a High Cost Operating Environment. IGI Global. In Press.

[2] The author can be reached via email: goran@roos.org.uk

[3] See e.g. Walker, 1887; Mundlak, 1961; Shashua et al. 1976; Mefford, 1986; Bertrand & Schoar, 2003; Alvarez et al. 2004; Cosh et al., 2005; Yukl, 2008; Bushnell & Wolfram, 2009; Baranchuk et al., 2011; Lazear et al., 2012; Balsmeier & Czarnitzki, 2013; Lin et al., 2013; Yonker, 2013.

[4] Bloom & van Reenen, 2007; Bloom et al., 2010; Bloom & van Reenen, 2010; Bloom & van Reenen, 2011; Bloom et al., 2012a; Bloom et al., 2012c; Bloom et al., 2012b; Bloom et al., 2013a; Bloom et al., 2013b

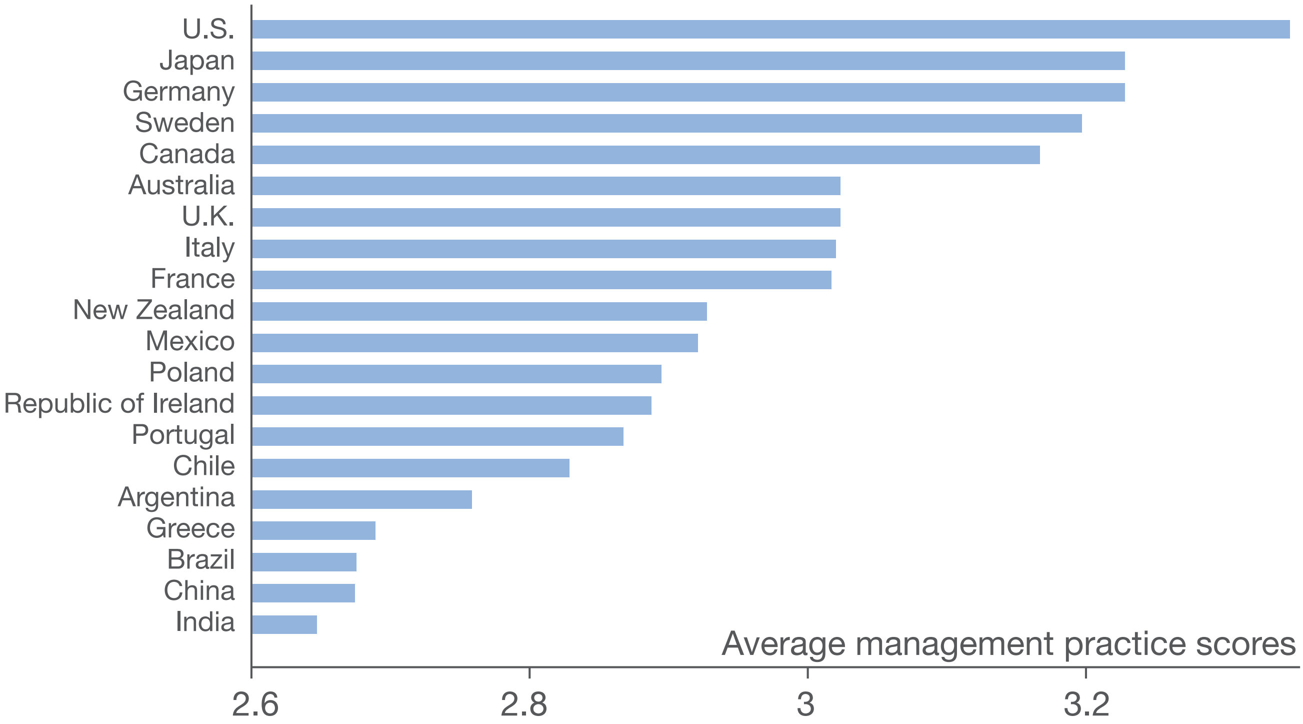


Figure 1: Management Practice Scores by Country (Averages taken across all firms within each country) (Bloom et al., 2013b, p. 73.)

The research by Bloom et al. also shows that there are two primary factors that are strongly correlated with management practice: the first is competitive intensity where higher intensity is positively correlated with high management practice score; the second is when family firms (which in themselves as an ownership structure are positively correlated with management practice) install the first son as a manager – which is negatively correlated with management practice.

Management capability matters and studies (Bloom et al., 2007; Green et al., 2009) show that a 17% improvement in management practice score is associated with the same increase in output as a 25% increase in the labour force or a 65% increase in working capital. The literature, as reported in Jarzabkowski et al. (2013) finds that management education has a general impact on the development of managers' skills and competencies[5].

Jarzabkowski et al. (2013) finds that formal management education does provide a basis for improving the use of management tools and techniques but that the effect depends on individual characteristics, so that formal business education, exposure to and frequency of management training, higher specificity of the training, seniority of corporate position and the relevance of the tools and techniques to the area of responsibility have a positive correlation; whereas age has a negative correlation. Lin et al. (2013) find that firms whose owners/entrepreneurs/managers received higher education had 5.2–5.8 percentage points higher return on equity, 115–126 percentage points higher profits, and 102–111 percentage points higher sales revenue, respectively, than firms whose owners/entrepreneurs/managers had not.

[5] Ishida, 1997; Kretovics, 1999; Baruch & Peiperl, 2000; Cheng, 2000; Priem & Rosenstein, 2000; Sturges et al., 2003; Simpson et al., 2005; Wren et al., 2007; Hay & Hodgkinson, 2008; Hall et al, 2013b.

High-performance work systems

These systems are not clearly defined but different studies have identified the key components of such systems and they have been summarised by Gibbons & Henderson (2012) and are shown in table 1:

Non mutually exclusive practices	Huselid, (1995)	Macduffie, (1995)	Ichniowski, Shaw & Prennushi, (1997)	Pfeffer, (1998)	Appelbaum, (2000)	Black & Lynch, 2001	Bloom & van Reenen, (2007)
Incentive pay	■	■	■	■	■	■	■
Skills training	■	■	■	■	■	■	■
Selective recruiting	■	■	■	■	■	■	■
Teamwork	■	■	■	■	■	■	■
Employment security			■	■	■	■	■
Information sharing	■			■	■		
Merit-based promotions	■				■		■
Flexible job assignment		■	■		■		
Reduced status distinctions		■		■	■		
TQM/Process Control		■				■	■
Communication			■		■	■	
Performance review	■						■

Table 1: Management practices underlying high-performance work systems. (Gibbons & Henderson, 2012, p. 18)

The findings from these studies seem to indicate that it is the complete bundle of practices that increases performance rather than the individual practices (Gritti & Leoni, 2012). It also should be noted that while some high-performance work systems in some contexts do contribute to enhanced performance, not all high-performance work systems in all contexts contribute to the desired outcomes (Boxall, 2012; Jiang et al., 2012). The identified productivity difference between using the complete bundle and using none of the identified practices seems to be in the range of 6 -7% . Another interesting finding is that the productivity benefits and the improvement of these benefits only accrue slowly – less than 10% improvement annually. Gibbons & Henderson (2012) point out that significant management practices require both managers and employees to act in ways that cannot be fully specified ex ante or verified ex post, so organisations must rely on relational contracts to implement these practices. This could explain the slow diffusion since three barriers may be encountered:

[5] Ishida, 1997; Kretovics, 1999; Baruch & Peiperl, 2000; Cheng, 2000; Priem & Rosenstein, 2000; Sturges et al., 2003; Simpson et al., 2005; Wren et al., 2007; Hay & Hodgkinson, 2008; Hall et al, 2013b.

- firstly, the relational contracts operated by high performing firms may be unfeasible or prohibitively costly for underperformers to implement (Gibbons & Henderson, 2012, p. 61);
- secondly, the sequence of events during a relationship can produce measured performance differences among ex ante identical enterprises: achieving perfunctory cooperation can make it harder to achieve consummate cooperation; cooperation, once built, can be fragile; and cooperation may be difficult to build in the first place (Gibbons & Henderson, 2012, p. 61-62);
- thirdly, difficulty in communicating the extensive task and relational information that underlies many relational contracts may also play a role in making it difficult to build unfamiliar relational contracts (Gibbons & Henderson, 2012, p. 62). This explanation is probably more important than other explanations put forward in the literature and listed here (Gibbons & Henderson, 2012):
    - Incumbent managers may not know that they are operating with a sub-standard performance[7].
    - Incumbent managers may know that they operate at a sub-standard performance but do not know what to do about it[8].
    - Incumbent managers may know that they operate at a sub-standard performance and do know what to do about it but have no (or negative) incentive to take action and adopt new practices[9].
    - Incumbent managers may know that they operate at a sub-standard performance but do not know what to do about it and they are striving to take actions to improve performance but cannot get the surrounding organisation to implement the necessary and identified actions to achieve the higher performance[10].

Higher Quality General Labour Inputs

Studies show that quality of labour is impacted by e.g. education, training, overall experience, tenure, etc[11].

Croce et al. (2013) find that highly educated employers have a greater propensity to invest in workplace training and also that close proximity between competing firms can lead to either a lower propensity to train workers due to the risk of poaching or a greater propensity to engage in training due to a positive knowledge spillover effect. Which of these two effects will dominate is a function of cultural traits where the latter dominate in Northern and Germanic Europe (through e.g. the apprenticeship scheme where firms routinely educate more people than they need themselves as a contribution to the industrial commons) and the former in Latin Europe and e.g. China. Sung & Choi (2013) found that internal staff training is a precursor for improved innovative performance which aligns with the findings of Kim & Ployhart (2013) that staff training drives firm productivity and growth and the findings of Aragon & Valle (2013) that show firms that train their managers with high frequency achieve better efficiency and performance than those that train their managers with lower frequency or not at all.

Kwon & Rupp (2013) find that the negative impact of high-performer turnover on firm performance will be strongest for reputable firms and for firms who invest less in human capital (e.g. selection, training, and incentive-based pay) which aligns with the more general findings of Osterman (1987), Alexander et al. (1994), Huselid (1995), Batt (2002) and Yanadori & Kato (2007) that there exists a negative relationship between turnover and firm performance; and the findings of Dess & Show (2001), Cross & Cummings (2004), Shaw et al. (2005) and Burt (2009) that high-performer turnover negatively influences firm performance because it results in more social capital loss compared with overall turnover since high performing employees hold more ties and have more network centrality. This complements the view of performance and that high performers' turnover is dysfunctional for firm performance but low performers' turnover in fact can be functional for firm performance (Dalton et al., 1982) since it allows firms to upgrade their human capital pool by replacing lower performers with more qualified people from the outside.

The conclusion is that firms should develop high performers and then maintain them in the firm with continuous capability development (i.e. life-long training of both managerial staff and the workforce in general), whilst speedily letting go low performers whose skills cannot be developed. This is going to become even more important given the increasing requirements posed by accelerating knowledge development in the domains underpinning the firm's activities, combined with shorter and shorter product life cycles.

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[7] See e.g.Henderson & Clark, 1990; Christensen, 1997; Tripsas & Gavetti, 2000; Ambrosini & Bowman, 2010; Kaplan, 2011.
[8] See e.g. Nelson, 1982; Winter, 1988; Winter, 1998; Almeida & Kogut, 1999; Anand & Khanna, 2000; Gant et al., 2002; Zollo & Winter, 2002; Lacetera et al., 2004; Winter, 2006; Breschi & Lissoni, 2009.
[9] See e.g. Reinganum , 1989; Bloom & van Reenen, 2007; Bresnahan et al., 2011.
[10] See e.g. Milgrom & Roberts, 1990; Milgrom & Roberts, 1995; Pil & MacDuffie, 1996; Rivkin, 2000; Bresnahan et al., 2002; Rivkin & Siggelkow, 2003; Siggelkow & Rivkin, 2005.
[11] See e.g. Amabile et al, 1996; Maliranta, 2003; Ilmakunnas et al., 2004; Shalley et al., 2004; Schneider et al., 2007; Jones et al., 2010; Chen et al., 2011; Naoki, 2011; Spiegelaere et al., 2013; Parrotta et al., 2014

Changing Structure

The migration of the manufacturing value adding potential from production activities to pre- and post-production activities as shown in Figure 2 has substantial implications for the required skill base in firms.

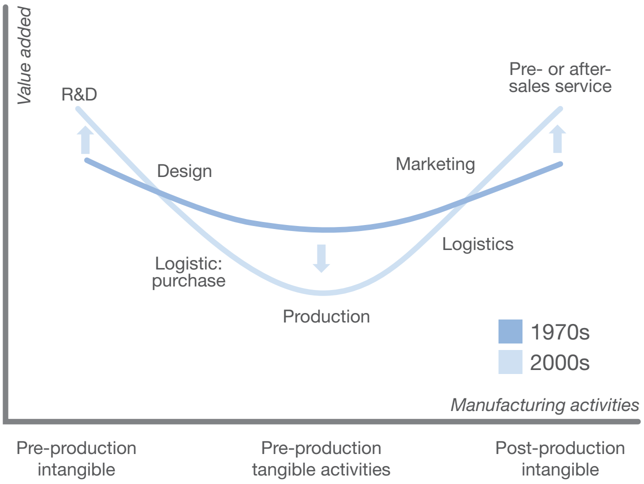


Figure 2: The shift in value-adding over time across the key value chain steps (Veugelers, 2013, p.27 after original concept by Shih, 1992).

As can be seen from the above curve and the fact that the trend identified in the curve will continue to strengthen, firms must extend their activities into the pre- and post-production phase of manufacturing as well as increasing these activities in order to stabilise or increase the total value creating potential. This move will require a broadening of the skill base in the firm not only into new technology domains but also into softer skills since human interactions become critical to the firm in many pre- and post-production service activities.

This above development is further strengthened by the increasing move to digital space of activities presently executed in physical space as outlined in Figure 3, and increases the pressure on manufacturing firms to servitize (some examples of this move to digital space are given in e.g. Ludwig & Spiegel, 2014).

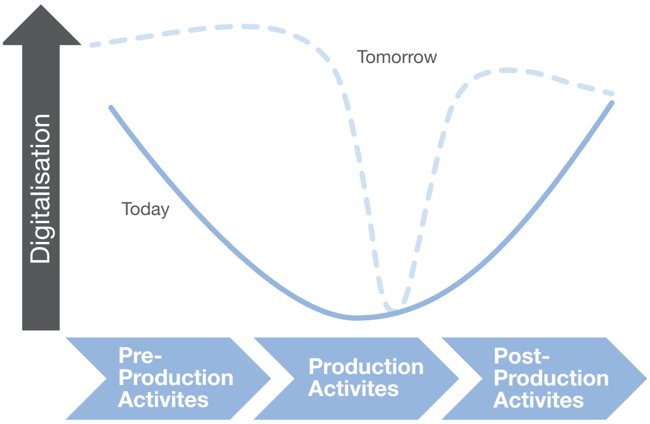


Figure 3: The increased digitalisation in the manufacturing activities (Roos, 2014a)

It follows that in addition to servitizing to compensate for the reduction in the value adding potential of production activities, firms will have to create service monopolies generated by product attributes that lock competing service providers out as well as by continuously innovating also in the domain of services which will enable temporary competitive advantages resulting in higher economic rent. This means that the firm will compete on value for money in a market where it ideally is the only firm able to provide services associated with a given product that it manufactures, hence becoming the highest value for money provider of the complete product-service-system offering in competition with other providers of competing product-service-system offerings or several cooperating or independent providers of products and services (Roos, 2014b). It is clear that this development will dramatically increase the skill requirement both as relates to deepening the knowledge in some domains e.g. ICT and broadening it in other domains e.g. human interactions.

Roos (2014b) summarises the work by numerous authors[13], into the most common tactical reasons and desired outcomes as relates to servitization as shown in Table 2:

[12] The first use of the term servitization in a context of manufacturing operations was by Vandermerwe & Rada (1989, p. 314). They defined servitization as "the increased offering of fuller market packages or "bundles" of customer focussed combinations of goods, services, support, self-service and knowledge in order to add value to core product offerings". Baines et al. (2009a) later defined servitization as "the innovation of an organisation's capabilities and processes to shift from selling products to selling integrated products and services that deliver value in use".

[13] Lewis, 1942; Levitt, 1983; Coyne, 1989; Reichheld & Sasser, 1990; Knecht et al., 1993; Anderson & Narus, 1995; Kalwani & Narayandas, 1995; Frambach et al., 1997; Desmet et al., 1998; van Looy, et al., 1998; Goffin, 1999; Wise & Baumgartner, 1999; Reichheld, 2001; Goffin & New, 2001; Mathieu, 2001; Nambisan, 2001; Munos, 2002; Davies,

Tactical Observation	Desired Outcome
Increased volatility in product sales [e.g. reduction of customer capital equipment spend in the mining industry]	Lower volatility in cash flows due to a balance of product sales revenues and after sales service revenues
Missing out on the revenue potential in the large installed base	Increase the revenue stream from the installed base and contribute to a reduction in cash flow volatility for the manufacturing firm
Loyal customers are easier to serve and hence cost less to serve and consequently are more profitable to serve	Increase profitability by leveraging economies of loyalty
Loyal customers have lower price sensitivity	Increase profitability by leveraging economies of loyalty
Loyal customers use more complex services that frequently are more profitable	Increase profitability by leveraging economies of loyalty
Loyal customers provide positive referrals and references to potential new customers	Reduce selling costs by leveraging economies of loyalty
Services are more difficult for competitors to imitate	Increased profitability due to the creation of competitive advantage, the duration of which can be extended through barriers to entry inherent in the difficulty to imitate
Services provision requires a closer relationship between producer and customer and may result in customer lock-in	This increases customer loyalty as well as providing a basis for competitive advantage and hence increase profitability
The product as a vehicle for service delivery, offers a potential for monopoly in some co-created services	Increased profitability through monopoly rent, economies of loyalty and in-depth learning which reduces the cost and risk around the development of both new products and new services
Continuous customer interaction speeds up the acquisition, volume and relevance of customer knowledge	Volume of innovation ideas increases and their market acceptance risk is reduced. Probability of co-developing new offerings with a lead customer is increasing thereby reducing market acceptance risk
Decreased interest in the product matched by increased interest in the outcome of the use of the product	The ability to partake in business operations that do not involve product sales but instead product use e.g. car sales replaced by car rental or car sharing
Service delivery with high customer satisfaction drives replacement product sales	Increased profitability due to repeat purchase
Some outcomes demanded by customers require service delivery	Retain market relevance, frequently combined with increased customisation of the complete offering
Some products require continuous service delivery over extended periods of time	Retain customer relationship
Offshoring or outsourcing of production	Substitute lost cash flow and earnings
Increasing regulatory requirements in the through-life and end-of life product responsibility domain	Services ensure regulatory compliance
Services can contribute to reduced environmental and resource footprint	Respond to market trends and reduce operating costs
Service provision adds another business	Increased turnover and (frequently) operating margin sometimes through increased opportunities for cross-selling
Services can differentiate the product offering	Increased competitive advantage resulting in increased profitability
Services can extend product life	On the one hand this increases the net present value of the earnings from a given product sale but on the other hand it reduces the net present value of new product sales so this needs to be managed very carefully

Table 2: Tactical reasons and objectives driving servitization in manufacturing firms (Roos, 2014b, p.)

A push towards servitization cannot be of limited scope since Fang et al. (2008) have found that servitization strategies typically require building a critical mass in sales, estimated to be 20–30%, before they can expect positive effects on firm value and that smaller outcomes than that may in fact have a negative impact both on firm value; and firm performance. Fang et al. (2008) also concludes that managers should focus their service initiatives on closely related businesses as much as possible to enhance synergistic spillover benefits and this fits with the above statement around achieving a monopolistic position as a provider of services linked to products manufactured by the firm.

Implementing servitization is challenging and in order to succeed servitization must be seen as a business model innovation not an offering innovation, and as such it requires interlinked changes in many dimensions. The dimensions, and the resulting business model, will be a combination of the dimensions outlined by Salkari et al. (2007) in their business-to-business service business model and the dimensions outlined by Roos (2013a) for a manufacturing business model. This need to combine the service and manufacturing business model is aligned with the findings of Visnjic & Van Looy (2013) in their study of a large durable industrial equipment manufacturer that has been actively pursuing a servitization strategy over the last decade. They found that these manufacturers enact complementarities between products and services by relying on an "integrated service business model", characterised by offering a variety of services related to the product activities of the firm. This ensures the effective deployment of a service business, but service activities also act as a driver of the product business. This reciprocal relationship between service and product activities is achieved in spite of the inherent substitution-type relationship that characterises products and related service offerings since successful service provisioning frequently leads to an extension of the in-use product life cycle (of existing products) and limits the potential sales of replacement products. Here, paradoxically, service-product relatedness leads to product cannibalisation if it was not for the managerial practices that ensure service-to-product complementarity (Visnjic & Van Looy, 2013).

Given the large variety of service offerings that are possible across the complete set of activities, pre-production/ production/post-production, as illustrated by Ren (2009) in his synthesis, the capability development that needs to take place inside a firm entering this domain is substantial. Raja et al. (2010) underline the importance of training requirements, as the development of new skills is a key to supporting the process of servitisation. Antioco et al. (2008) also found that employee service training is important: the ability to generate service volume through a services in support of the client's actions -business orientation grows significantly with more service training. To customize a service, sellers must possess the skills to listen and appeal to the purchaser.

Competence development in general is key in the transition to service innovation. This training is done with the general objective of increasing the human capital of the firm in order to both increase the firm's absorptive capacity as well as increasing the opportunities that can be identified for innovation (Cohen & Levinthal, 1990). Since the total human capital of the firm is the repository of the firm's tacit knowledge (Johnson et al., 1996) a commitment to the development of human capital through training programmes is likely to be critical to successful innovation (Freel, 2006). There is statistical evidence indicating a high importance of human capital for innovation in a wide range of manufacturing industries and countries (Mohnen & Röller, 2001) and this is supported by Walsworth & Verma (2007) who show that training appears to have a positive impact on both product and process innovations and Beugelsdijk (2008) who indicates the importance of training for generating incremental innovations as well as Amara et al. (2008) who find that variables related to learning by training have a relevant impact on the degree of novelty of innovations and Rammer et al. (2009) who show the importance of applying human resource management tools (including training) to facilitate innovation processes. The literature suggests that human capital and training are crucial factors for innovation in both manufacturing and service firms. Raja et al. (2010) underline the importance of training requirements, as the development of new skills is a key to supporting the process of servitisation.

The driving force to extend the manufacturing firm's offering to include services can be expressed as a move from an incomplete offering in a product-focused transaction-based customer relationship, to a complete offering (i.e. the bundling of products and services to better meet defined customer needs) in a relational-based customer relationship[14].

The conclusion from this section is that the firm must develop an offering that combines products and services, where the total bundle provides the highest value for money from the customer's perspective and where the services that are part of the bundle can only be supplied by the firm due to their unique coupling with the product and where the products can only be produced by the firm due to unique features built into the product or unique attributes of the production process. And this cannot be done without dramatically deepening and broadening the firm's competence base.

Changing Technology

The structure of manufacturing will be impacted by developments in a set of key technologies and systems of technologies like production systems. Some of these developments have potentially transformative structural implications and are linked to Key Enabling Technologies[15]

[14] See e.g. Tellis & Stremersch, 2002; Penttinen & Palmer, 2007, Kowalkowski et al., 2009.

[15] Key Enabling Technologies are technology domains that are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure, highly-skilled employment, and that not only underpin most industrial activities across sectors but that also form industrial sectors in their own right. They include in the author's definition: Information and Communication Technologies, Nanotechnology, Micro- and Nano-electronics, Industrial biotechnology, Photonics, Advanced materials and Advanced manufacturing Technologies.

and Production Systems for high cost environments[16].

Given the rapidly increasing technological sophistication of products, production processes, production equipment and production systems, tomorrow's manufacturing workforce will be required to have substantially higher skills including new knowledge domains like e.g. ICT (hardware, sensor and software skills); sufficient technology competence to understand the key production process/ equipment e.g. nanotechnology, biotechnology, advanced manufacturing technologies, material science etc. and key skills required for participating in and contributing to a high performance workplace environment e.g. problem solving , interpersonal collaboration, etc. This will require a substantially higher level of formal education on entering the workforce complemented by continuous education to stay productive in this future manufacturing environment. In this environment a non-updated high skill level individual will, without continuously updated skill, continue to be productive for a maximum of three years [and this number will continuously decrease].

> *"Modern manufacturing requires teamwork, planning skills, communication skills, improvisation, agility of the mind, and a large foundation of knowledge"*
> Mitchell (2012).

The lowest level of education is likely to be the highest level of VET (or technical colleges) including joint programs with industry, whereas the norm is likely to be Bachelor level university degrees. There is already a clear link in high cost operating environments between the educational attainment of both management and the workforce and productivity improvements . In addition, the effects of productivity growth and liberalised trade tend to be felt disproportionately by low-skilled workers (Berman et al., 1994) resulting in fewer employment opportunities for them (Deitz & Orr, 2006). The need for STEM graduates will accelerate as a consequence of these shifts and the availability of these graduates is a prerequisite for manufacturing moving back to high cost operating environments. A more detailed discussion around the emerging skill production system for manufacturing can be found in Weaver & Osterman (2014) and of the emerging skill need in Davis et al. (2012).

In spite of these efforts it is likely that the skill level of individuals involved in R&D will not be able to be kept up-to date and that the organisation instead will have to change the career path to one where most new graduates commence in R&D and then follow the product generation into production, installation and after sales service.

Given the servitization of manufacturing and the increasing tradability of services and service activities, it will be challenging for those high cost operating environments that do not manage to retain or recoup manufacturing activities, that do not mange to have enough entrepreneurial activity to regenerate high value adding activities, and that do not manage to add value to domestic raw material. This challenge will be around the level of employment available and the general salary level of this employment. This is because these jobs will be in service professions where productivity improvements are either impossible or undesirable, where any wage increase will result in a cost increase since it cannot be offset by a productivity increase (Baumol's disease[18]) and hence the relative cost for these services will tend to increase faster than the consumer price index. This is acceptable for luxury services, but not for non-luxury services where this will instead force constant wage reduction to keep the cost constant in relative terms .This presents a major political challenge because it will affect a large and growing number of people in such an economy (well exemplified by the present trajectory of Australia).

Conclusion

A review of the literature finds that manufacturing in the future will require higher levels of education of both managers and employees and that this education process will be required to be continuous (i.e. life-long learning will be a requirement for survival let alone success). There is also some evidence that high performance work systems, when implemented as a complete system have positive performance impact on the firm and skills development is an integral part of such a system. These findings of course support the fact that firms with low turnover of skilled employees and managers have higher performance than firms with high turnover. The continuously increasing speed of technology change will require a higher initial education level of the workforce in manufacturing (minimum level likely to be the highest achievable level of VET education) combined with continuous life-long learning. In spite of these efforts it is likely that the skill level of individuals involved in R&D will not be able to be kept up-to date and that the organisation instead will have to change the career path to one where most new graduates commence in R&D and then follow the product generation into production, installation and after sales service. The skills required in manufacturing will also be much broader than the traditional technical skills and will encompass substantially deeper and broader skills related to teamwork, planning skills, communication skills, improvisation and agility of the mind. This will be further broadened as a consequence of the servitization of manufacturing that is presently taking place. This development will require broad human interaction skills.

[16] These include Individualised Production, defined as a concept for the design and layout of all elements of a production system in such a way that it permits a high degree of variability in the production programme whilst maintaining production costs on a level comparable to that of mass production; Virtual Production Systems are deployed in the development of new products with the objective of reducing time and resources used for non-productive planning activities prior to the actual value creation; Hybrid Production Systems build on a combination of production technologies based on differing physical principles or the integration of separate production processes into a single, new production process; Self-Optimising Production Systems possess an inherent intelligence and have the capability to adapt themselves autonomously to changing ambient conditions in order to achieve greater process flexibility.

[17] See e.g. de La Fuente (2011). For a discussion of the literature here

[18] So named after being first described in Baumol & Bowen (1966).

Dr Swee Mak: Technology trends and their impact on future manufacturing

Swee L. Mak and Peter King, CSIRO Future Manufacturing Flagship

Introduction

Manufacturing in Australia is experiencing continuous pressure to be more globally competitive. This is due to a combination of factors, including the impact of a relatively high Australian dollar, the shift in investment into the resources sector and also what is described as the increasing cost of doing business in Australia. Along with some other industry sectors, relatively flat productivity growth is also an underlying issue for the manufacturing sector. The more recent decisions by major automotive manufacturers to exit operations in Australia has put further pressure on many firms that make up the automotive supply chain, particularly automotive component manufacturers. This has prompted even deeper thinking about how manufacturing firms can stay in business and remain competitive e.g. through diversification [1].

Over the last few years considerable thought has gone into how Australia can sustain a competitive manufacturing sector. Apart from measures associated with the macro-economic and regulatory environment, there is wide acceptance that manufacturing firms need to embrace various forms of innovation [2, 3, 4]. Innovation is not all about technology and broadly encompasses how firms employ innovation in skills, managerial processes and business models to remain competitive. However, technology can be viewed as both an enabler and a disruptor for business. There are technologies that can assist businesses become more efficient or effective in their operations and assist a firm in leapfrogging ahead of its competitors. Then there are technologies that have the potential to disrupt the business model of a firm leading to short/long term operational impacts.

Future trends and implications on manufacturing

So what will manufacturing look like in 2030 and more importantly, how might technology either assist or disrupt manufacturing firms? Short of having a crystal ball to gaze into, one way to think about the future manufacturing landscape is to examine some of the forces that may shape what consumers increasingly want, and therefore, how manufacturing firms are likely to respond. Coupled with macro-economic or regulatory factors that are likely to influence the way manufacturing firms operate, we can begin to develop a view of future scenarios. Of course we should always be cautious in over-generalising potential future scenarios. This is particularly so in the case of the relatively broad and diverse manufacturing sector which comprises a large number of often small firms that operate across multiple market segments. In the Australian context, some market segments are experiencing gradual decline e.g. automotive whilst others are experiencing considerable growth e.g. bio-tech. Therefore, the factors that drive competitiveness and long term sustainability of firms across a diverse sector are expected to vary considerably.

An analysis of mega trends is one way to form a broad picture of plausible future scenarios from which we can think about implications for manufacturing firms. In the CSIRO's contribution to the Prime Minister's Manufacturing Task force [3, 5], a number of mega-trends and their potential implications on manufacturing were analysed (See Figure 1). A megatrend is defined as a major shift in environmental, social and economic conditions that will substantially change the way people live. In its most recent analysis [6] the CSIRO identified six interlinked mega-trends, which can be summarised as follows:

- **More from less** explores how companies, governments and communities will discover new ways of ensuring quality of life for current and future generations within the confines of the natural world's limited resources.
- **Going, going... gone** explores the perilous situation of the world's ecological habitats and biodiversity.
- **The Silk Highway** explores the implications from world economy shifting from west to east and north to south, accompanied by rapid income growth in Asia and, to a lesser extent, South America and Africa, with billions of people transitioning out of poverty and into the middle income classes.
- **Forever Young** explores the likelihood that people will retire later in life, gradually wind back and change duties in a tapered model of retirement and spend increasingly large sums of money through the healthcare system to combat age related illnesses.
- **Virtually here** explores what might happen in a world of increased connectivity where individuals, communities, governments and business are immersed in the virtual world to a much greater extent than ever before.
- **Great expectations** is a societal and cultural megatrend that explores the rising demand for services and experiences over products. It also captures the expectation people have for personalised services and the rising importance of moral and ethical dimensions for consumers.

Trends and their Impacts on Manufacturing

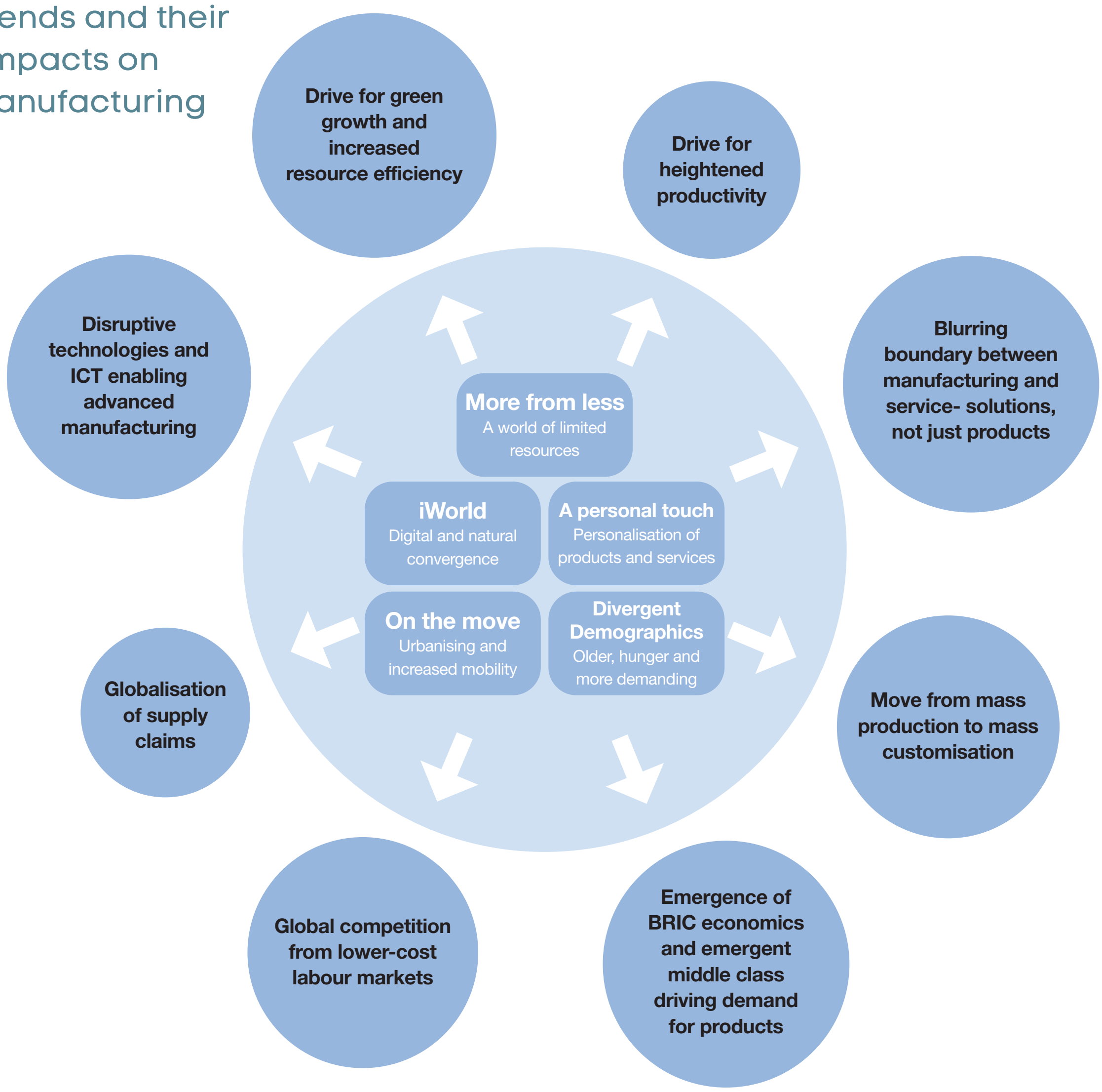


Figure 1 Megatrends and their potential impacts on manufacturing [3]

What this megatrend analysis implies for future manufacturing is that in an increasingly connected and networked world where consumers value experiences associated with products, and with an expectation of a high degree of personalised service, businesses need to be much more responsive to specific consumer preferences and there will be a blurring of the lines between products and services. It might be reasonable to expect that manufacturing firms of the future generally are expected to show a much higher degree of agility in what they do and how they do it. Amongst other things, this means manufacturing firms need to:

- understand and respond to consumer insights much more quickly that they can currently do;
- personalise or customise products and services to meet more specific needs of customers, implying a need to increase capacity for innovative design and flexible production;
- shift from what was predominantly a mass production paradigm that focused on efficiencies, economies of scale and repetition, to one of mass customisation where firms are able to capture value from providing highly customised offerings with near mass production efficiency. This implies that in some cases, manufacturers are able to generate value and profitability from relatively low volumes of highly customised production [7]. The shift to a higher degree of customisation also implies that highly scalable production technologies that enable rapid changes in production volumes will also become increasingly relevant. Consequently manufacturing operations may shift from larger scale operations to lower footprint, distributed or networked models of production and distribution;
- shift from capturing value solely from producing and selling products to creating knowledge and selling experiences and services, continuing the trend of servitisation of manufacturing businesses; and
- understand that consumers and governments have increasingly high expectations on how businesses manage resources and the impact of their business activity on the environment and society, along with greater transparency and communication around these concepts. Hence there is a need for firms to understand and preserve their social license to operate.

Technology trends

We often think about manufacturing technology in terms of materials and processes that are involved in making things. However, if we start with the premise that in the future, many manufacturers are as likely to be integrators and service providers that focus on creating high value, highly customised experiences for consumers in a highly digitally connected world, then our framing of future technology begins to widen. A recent survey of different perspectives on future technology trends undertaken by the CSIRO's Agile Manufacturing Technologies team reveals a high degree of consistency in the major technology platforms that are seen as relevant for future manufacturing (See Table 1). Some of these key future technology platforms include:

- Advanced materials
- Biotech, genomics and medical devices
- New production processes
- Harvesting value from waste & Clean water solutions
- Clean energy and energy storage solutions
- Big data and analytics
- Human computer interface
- Personalisation of IT
- Cloud computing services.

From this perspective, CSIRO is undertaking research across the wide range of technologies identified in the various reports, as shown in Table [1]. Thus the CSIRO is well positioned to assist Australian manufacturing in a globalised economy where all of these technologies are in play by providing a bridge for Australian industry in exploiting these technology trends.

Technology Description	World Economic Forum List of Emerging Technologies - 2014	Gartner 2013 Hype Cycle	Deloitte - Transformation of Manufacturing & Tech Trends	Accenture Technology Vision 2014 & FJORD	KPMG Converging Technology Trends 2013	Global Futures and Foresight - What's hot in 2014 - Tech Trends	McKinsey Global Institute - Disruptive Technologies - May 2013	Frost & Sullivan - Techvision 2020	Report to the US President - June 2011	CSIRO
Personalisation of IT - Wearable Electronic, Mobile Technologies & Consumerisation of IT and BYoT, Screenless Display	✓	✓	✓	✓	✓	✓	✓	✓		✓
Biotech, Genomics & Medical Devices	✓						✓	✓	✓	✓
Big Data and Analytics	✓	✓	✓	✓	✓	✓	✓	✓		✓
Human Computer Interface	✓	✓	✓	✓		✓	✓	✓	✓	✓
Advanced Materials - Nanotechnologies, Carbon Fibres, Composites	✓		✓				✓	✓	✓	✓
Harvesting value from waste & clean water solutions	✓							✓		✓
Clean energy & Energy Storage solutions including smart buildings	✓					✓	✓	✓	✓	✓
New Production Processes - eg. 3D printing, Apps, Embedded systems, Smart Sensors, Flexible electronics		✓	✓	✓	✓	✓	✓	✓	✓	✓
Cloud Computing Services, the IoT & the Connected & Collaborative economy		✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 1 Technology trends relevant to future manufacturing (sources as indicated)

In this article, we shall focus discussion on several of the technologies that are likely to feature in a digitally connected, knowledge based advanced manufacturing environment, such as:-

3D printing or additive manufacturing

It is impossible to escape the excitement that is building around 3D printing or additive manufacturing. Every day, we hear about new advances in both research and application of 3D printing technology to make objects or products in novel ways using a variety of materials, including polymers, metals, ceramics and even biological materials. However, the big question is whether 3D printing can become a cost effective mainstream technology that will assist manufacturing firms become more competitive.

It is important to firstly understand what 3D printing can do [8]. Being an *additive technology*, 3D printing can offer significant cost savings by using lower amounts of material than traditional manufacturing methods. For instance, an additive method that builds up a metal component layer by layer using molten metal powder or wire will use less materials compared to a traditional 'subtractive' method where the required part is machined from a large block of metal producing potentially a large amount of waste metal scrap. This therefore, provides a 'resource efficiency' benefit.

If the manufacturer of the future needs to develop an ability to rapidly customise products to meet low volume consumer demands, then 3D printing has the ability to significantly shorten the time a product spends in the design cycle before it reaches the market. Multiple iterations of product design variations can be explored simultaneously during the conceptual stage of design, without investing in the tools to make the product [8].

Whilst there are many different 3D printing techniques and materials being used, one common feature of these techniques is the ability to construct objects of complex shapes and features. This lends the user a capability to manufacture highly complex products that simply cannot be produced with a conventional method. This also enables the manufacturer to rapidly produce once off products without a large investment in tooling or moulding equipment as well as being able to combine two or more simple parts, prior to assembly, into one large complex component.

However, the big question is whether 3D printing can become a cost effective mainstream technology that will assist manufacturing firms become more competitive. Our experience is that the potential impact of this technology cannot be generalised and manufacturers need to understand the impact of cost versus benefit gained for every part that they make. Manufacturers also need the appropriate business models that can allow them to fully exploit the advantages offered by this relatively nascent technology.

Automation and robotics

Globally we are seeing a major shift towards technology-led manufacturing focused on large scale industrial automation. In Australia, where manufacturing is dominated by a large number of small firms, many of these SMEs often find it difficult to embrace industrial automation because of cost and the risk of disruption to their production. However, there may be other paths to large scale industrial automation. Simple repetitive tasks have largely been addressed by automation (robotics) in manufacturing environments. However, there are many complex tasks that still require human involvement. It may be these technologies that 'assist' (rather than replace) human processes that may become more prominent in Australia. The emerging field of assistive automation may play an important role in the future of Australian manufacturing [9].

Through a series of industry consultations, the CSIRO established that manufacturing firms need/want to increase their level of automation and implement technologies to help [10]:

- **make the workplace safer** by using robotic systems that help orient, lift and manipulate components so that workers can assemble them with greater precision in manufacturing lines whilst reducing occupational health and safety risks. This is particularly relevant in hazardous or highly repetitive tasks that make workers vulnerable to repetitive-stress injuries;
- **increase productivity** using assistive robots that help increase worker production output;
- **improve product quality** by using technologies that reduce misalignment and incorrect assembly of components as well as the amount of time taken for inspection and certification;
- **reduce set up time and down time** using a range of assistive automation technologies that enable productivity improvements e.g. reduction of set-up time through automated jig recalibration (allowing a manufacturing process to produce different goods), or via virtual capture and replay of processes to identify timesaving opportunities; and
- **extend workforce participation for older workers** - faced with an ageing workforce, Australian manufacturers are keen to retain skilled employees by using technologies that allow employees safe and productive extended working lives, and to facilitate phased retirement programs.

The field of robotics is changing [9]. Conventional industrial robots are generally heavy, programmed for a limited number of specific tasks, fixed in place on the factory floor, and relatively expensive to buy, install, program and maintain. They are also potentially hazardous to humans, so workers are usually excluded from the robot workspace. The next generation of robots is different however, as they are lightweight and include a number of technological advances in spatial awareness, mobility, human-machine communication, manipulation technology and new advanced materials. Lightweight robots can be integrated into the Australian workplace as assistants to workers in a number of ways, including:

- **intelligent tools** which work together with human workers including mobile assistants, manipulators, 'smart' picking, lifting and handling systems, robotic welders, gluers and assemblers. These enable automation of short-run production processes, and provide a flexible solution to increase efficiency of production;
- **human augmentation systems,** including powered exoskeletons that enable workers to lift and manipulate heavy loads safely, wearable vision systems that can alert workers to workplace hazards and tele-immersive training systems that enable experienced staff to remotely mentor workers who are new to a work environment; and
- **'smart' field tools,** including tele-operated mobile tools, rigs and virtual/augmented reality systems which facilitate micro-manipulation and micro-assembly to enable workers to conduct complex tasks whilst reducing repetitive strain and over-use injuries.

ICT and a knowledge based, digitally connected advanced manufacturing environment

The transition of Australian manufacturing towards a knowledge based, highly networked, flexible and agile industry sector will undoubtedly be accompanied by an increased adoption of information and communication technologies. Robotics and automation represent only one element of an integrated vision of a digitally interconnected advanced manufacturing environment. The CSIRO's vision is of an advanced manufacturing environment in which Lightweight Assistive Manufacturing Solutions (LAMS), comprising ICT systems and services, the workforce and autonomous systems are able to seamlessly, reliably and safely collaborate, as shown in Figure 2 [11]. Four interlinked technology capabilities have been identified to underpin this advanced manufacturing environment ie Human Machine Interfaces (HMI), Robotics, Informatics and Perception.

- HMI and Robotics lead to advances in mobile tele-presense. *The ability to go anywhere …*
- HMI and Informatics lead to advances in social networking and thus *to collaboration …*
- Robotics and Perception lead to the development of lightweight robotics – *solutions that are low cost and easy to deploy*
- Informatics and Perception lead to advances in Digital Worlds – *where the virtual worlds available on the Internet will 'mirror' what is happening in the real world.*

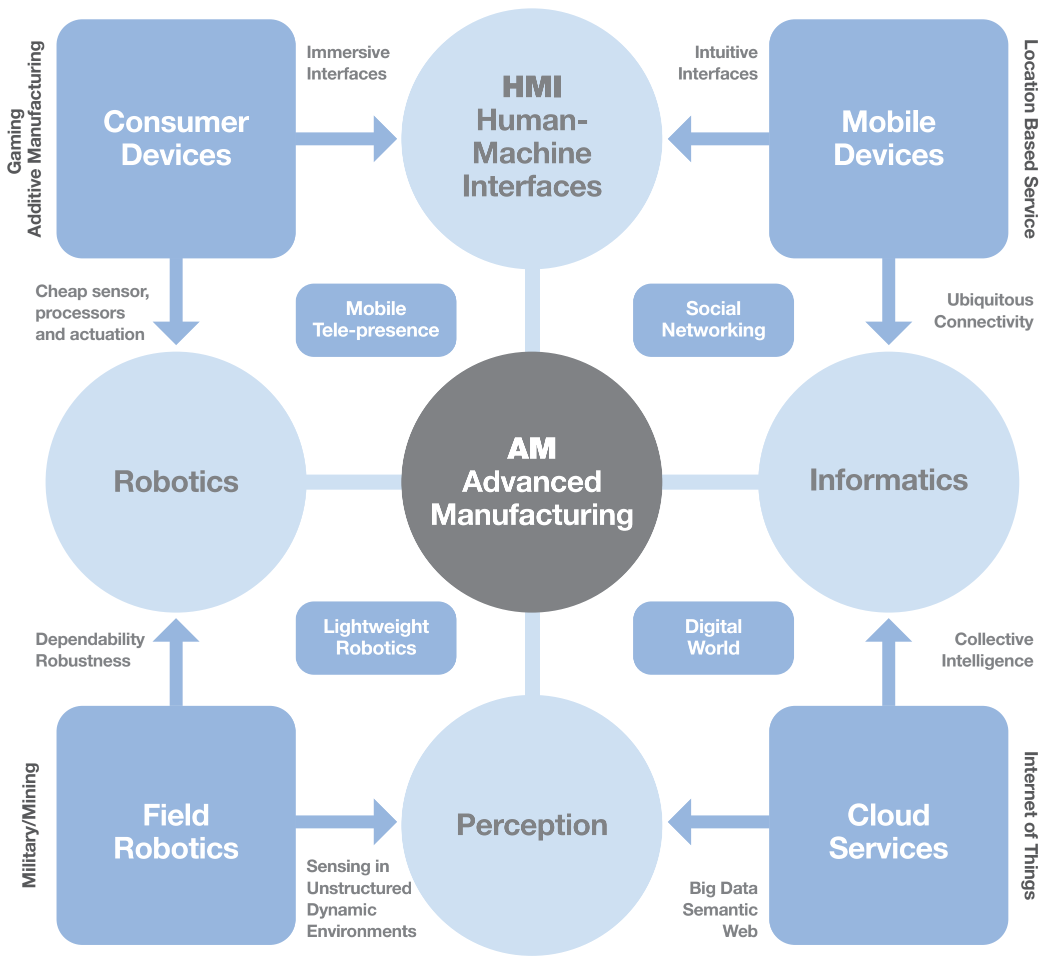


Figure 2 Current and emerging technological trends underpinning the development of lightweight assistive manufacturing solutions

To maximize the return on investment on such technologies, the four capabilities must be implemented in a seamless and cooperative manner. Booz & Co [12] noted that "companies that made significant use of these digital enablers were 77 percent more likely to report that they outperformed competitors than were those with low or moderate usage rates". Further value will be realized in combining these techniques to produce novel 'fit for purpose' solutions. In the context of earlier discussion on the transition paths for Australian manufacturing, *fitness for purpose* for Australian advanced manufacturing specifically relates to the ability to:

- Be highly responsive with great customer insights and connections;
- Deliver customised solutions rapidly - flexibility in scope; and
- Excel at low volume manufacturing – while maintaining the ability for high scalability – such that production can adjust easily to different volumes.

According to the US National Institute of Standards and Technology [13], there are key elements that define and, thus enable flexible advanced manufacturing environments from the factory floor to communication across the supply chain, namely:

- Mobility across dynamic and unstructured environments;
- Autonomous (or semi-autonomous) operation in uncertain or unstructured environments;
- Ability to manipulate and interact with a changing external environment;
- Capability to achieve desired outcomes without the need for a fully pre-programmed script;
- Ability to perform tasks in close operation with humans; and
- Ability to augment the reality or the physical capabilities of a human user.

Implications on skills for the future

The introduction and application of these new technologies will require an integrated response across the national innovation system. These new technologies are also social in nature and change the way we think about collaboration and the ways in which machines and humans interact. Accordingly, new skills will need to be developed and adopted to take account of these new technologies. In many cases, current skill sets can be applied to new technologies with minimal training. In its 2013 Survey of Manufacturing skills, the Manufacturing Leadership Council in the USA identified engineering and technical skills as key academic skills needed in Manufacturing, as shown in Figure 3 [14]. These skills underpin an understanding of the design and application of new technologies that can foster implementation and uptake in the manufacturing environment. In terms of functional skills the same report identified understanding lean manufacturing principles and having collaboration skills as rating highly along with computer proficiency, design and sales expertise (Figure 4). Together these sets streamline the incorporation of new technologies and allow efficiencies generated on the factory floor to be transformed into a competitive edge for the firm.

The emerging field of assistive automation may play an important role in the future of Australian manufacturing.

Engineering, Technical Skills Dominate Future Skill Needs

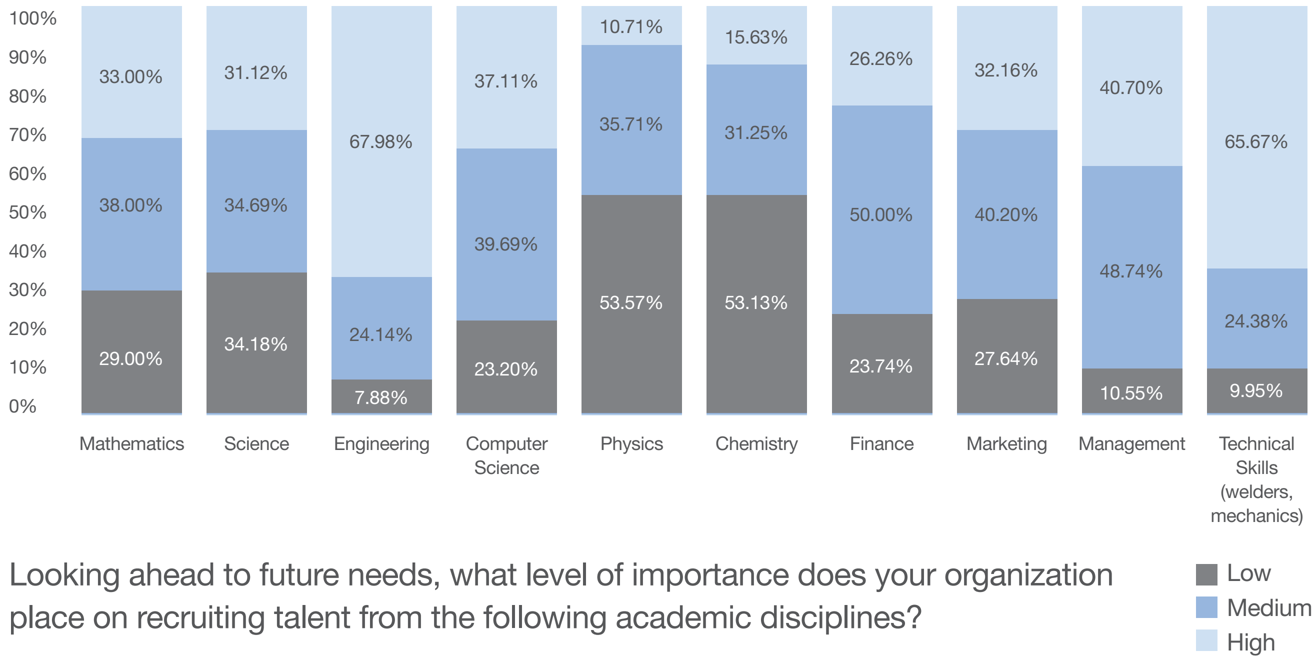


Figure 3 Future skills needs – academic disciplines [14]

Collaboration, Lean Skills Lead Future Functional Requirements

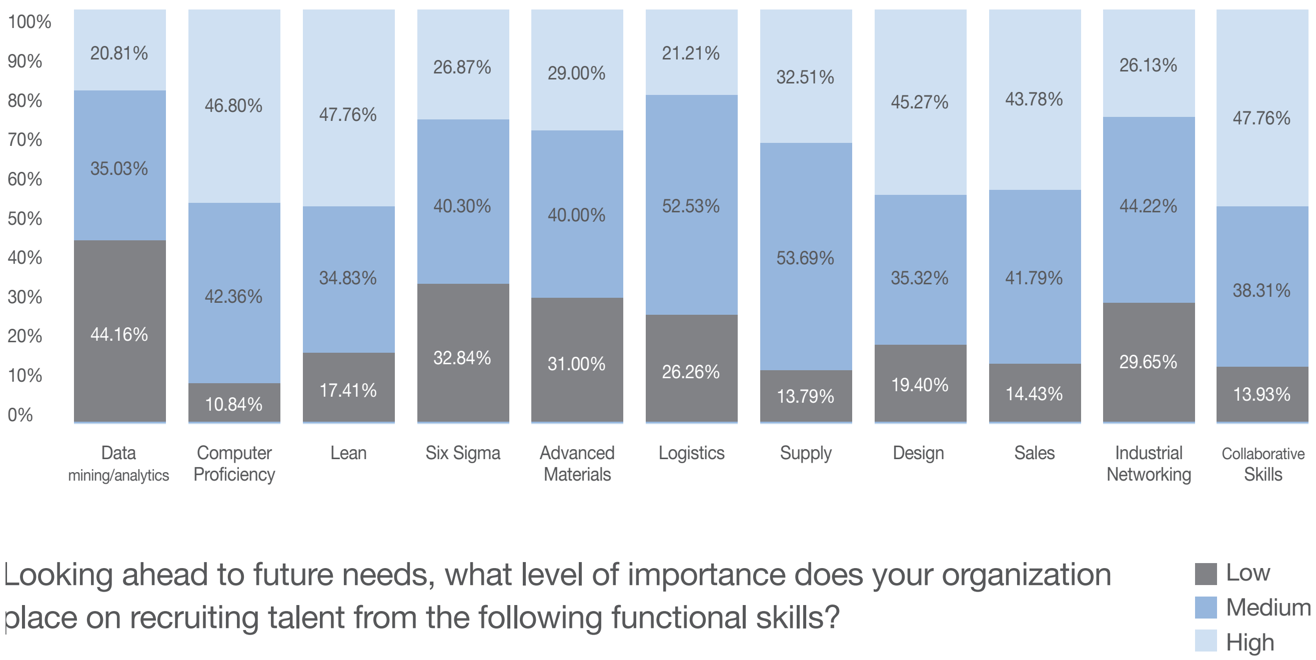


Figure 4 Future functional skills needs [14]

The advent of crowd-sourcing to develop new products also provides a new way of undertaking business and will potentially have a significant impact on the workforce of the future, using kaggle for example to solve big data problems [15]. In terms of multi-disciplinarity, the skills needed for the future will not only relate to the technologies themselves, but will also focus on leadership and development of culture throughout the organisation. An understanding of the need to develop new business processes and models will be required to capture the benefits that these new technologies create.

Generally, companies will require a cadre of leaders with diverse skills, experiences, and capabilities to address the different challenges facing the manufacturing sector and seize the opportunities. In order for technology companies to drive their organizations forward, leaders should be agile, mindful, assertive and design-led; all skills necessary to challenge the current state and look to the future to implement innovative solutions faster than the competition.

Professor Sam Bucolo,
Professor Design and Innovation, UTS

The key issue is how can all players contribute to building up the adaptive capacity of firms and individuals?

Professor Sam Bucolo: Design Led Innovation – Underpinning a Future Manufacturing Workforce

This 'think piece' provides a provocation to stimulate the discussion on what is the role and value of design led innovation to underpin a future Australian manufacturing workforce. The paper draws on many disparate threads from the author's research, practice and collaborations to highlight why design as a process should be considered a mandatory skillset which will be required by a future manufacturing workforce.

Manufacturing today and the case for a changing mindset

The Australian Manufacturing sector has been and continues to be buffeted by the effects of the global economy, highlighted by having a high cost environment, challenges to productivity growth, diminishing terms of trade and characterised by having weak management skills. However in the midst of these challenges it is the author's firm belief that Australia's manufacturing sector will continue to play an important part in the economic environment.

There is consensus that Australian manufacturing is a highly efficient sector as evidenced by its ongoing resilience and modest growth in difficult conditions; and additionally, that manufacturing firms are responsible for a significant level of current technology-based R&D, although this lags behind many of our competitors. The sector reflects the Australian characteristics of resourcefulness and pride in quality: many of these businesses are family businesses, having started from very little and handed on between generations. It is from this solid foundation, which firms must transform and diversify to address the challenges which are generally understood to be:

- Australia produces a comparatively low proportion of high technology goods in primarily niche application areas.
- Industry faces challenges from an ongoing albeit slowing resources boom, high labour costs and an uncompetitive exchange rate.
- Emerging economies are expected to dominate manufacturing in the near future with an associated decline for most developed economies.
- In contrast, Australia's performance has stagnated – in the face of fierce global competition.

- Global manufacturing trends include a move toward distributed global value chains, fragmenting customer demand, increasing skills gap and high technological changes.
- Manufacturing policies in developed countries and regions such as the US, Scandinavia and the EU are being revisited to stimulate domestic situations.

Although these challenges may be clear, strategies to address these are nascent and less understood by the sector.

The impact of a declining manufacturing sector is of a national concern, as it will impact on Australia's decline in global competitiveness. Competitive economies drive productivity enhancements that support high incomes by ensuring that the mechanisms enabling solid economic performance are in place (see the World Economic Forum Global Competitiveness Index – GCI). For advanced economies such as Australia (categorised by the GCI as 'innovation driven economies'), greater emphasis is placed on these capabilities relating to business sophistication and innovation as drivers for maintaining competitiveness. While Brazil and Asian economies are expected to dominate over the coming years, in contrast to its regional neighbours Australia is expected to decline in competitiveness.

It is clear that the Australian manufacturing sector needs to make changes to compete in a globally changing economic landscape. Adopting new forms of innovation will be one of the critical success factors.

Traditionally, the answer to the question of what drives competitiveness and productivity in advanced economies has been the technological change and innovation embodied in capital equipment, but more recent evidence suggests that non-technological innovation, such as management capability and business model innovation is just as important, if not more so.

In a low cost economy, a common route to success in manufacturing business is imitation, whereas in a high cost environment it is innovation. In a low cost environment, most factors of production are available at lower or similar cost compared with other locations. With the development of technology and increased globalisation, the share of factors of production available at similar cost increases, making the remaining factors of production available at lower cost increasingly valuable as a basis for the firm's competitive advantage. These remaining factors tend to be linked to national or regional comparative advantages, such as minerals, agricultural land or produce, low population-density land, biodiversity, and university educated people.

In a high cost environment, approaches to innovation differ significantly.

> *Rapidly advancing technologies in areas such as biomanufacturing, robotics, smart sensors, cloud-based computing, and nanotechnology have transformed not only the factory floor but also the way products are invented and designed, putting a premium on continual innovation and highly skilled workers p8 … (However) a new paradigm is needed for making value which … is larger than "making things." Making things (i.e., manufacturing) is often an important part, but making value requires an integrated system of understanding customers, R&D, design, manufacturing, and the delivery of products and services. This integrated system requires the creation and delivery of value in the marketplace with a sustainable business model for the enterprise producing it … it is a customer-focused process of connecting important needs with new knowledge.*
> (National Academy of Engineering p19)

While technical ingenuity may be found in many Australian workplaces, Australia lags behind other advanced economies in areas including the investment (both human and capital) in non-technological innovation. It is from this perspective where design as a process offers greatest value to a future manufacturing workforce.

However, and it will be a large however, to achieve this transition within the Australian Manufacturing sector, it will require a significant shift in mindset and support. It will require manufacturers to ensure they continue to invest in STEM based innovation but also in the "soft science" disciplines such as design. As noted by Ian Chubb and Jennifer Westacott (National Drive for more Innovation, AFR 26 August 2014, p48)

> *… it will be people, ideas and innovation that underpin a successful Australian economy… This starts by ensuring school students have the world's best literacy and numeracy skills. It also means starting to equip students early in science, technology, engineering, and mathematics (STEM), as well as so called "soft skills" like adaptability, design thinking and problem solving.*

Shifting mindsets

Many Australian enterprises are stronger in operations management than people management (Green et al 2009). While they are able to link employee performance with clearly defined accountability and rewards, they lag in their deployment of advanced people management practices. These include attracting, developing and retaining talent, and identifying innovative but practical ways of developing human capital to improve performance and add value to organisations. A focus on people and culture within organisations will also enable organisations to adopt a culture of risk and flexibility which is based on trust and good leadership and management practice.

Compared with international best practice, Australia tends to fail to 'instill a talent mindset', this is essentially a proxy for innovation and design capability. To improve, Australian managers must give more attention to building their people management skills and the relationships within their organisations. There needs to be more management education and a focus on creativity and integrated thinking to enhance the performance of manufacturing firms. A 'learning by doing approach' is also recommended as being key to ensuring that new skills are embedded.

> *'A key finding of our research is that focussing on the critical mass of poorly managed manufacturing firms within the country is the most effective way of enhancing Australia's overall management capability and performance.'* (Green et al 2009)

Seeding and improving the productivity of manufacturing through initiatives and investments in management skills is worth greater attention. A high level of management quality and expertise enables firms and organisations both to develop internal dynamic capabilities and sustainable competencies (Green et al 2009). Building design led innovation skills throughout business has the potential to address this management capability gap.

Design thinking capability

The importance of design to a firm's innovation has been the subject of much previous research particularly in the design and development of new products. However more recently it is now widely understood that design can add significant value to a firm's strategic capabilities beyond the development of a product or service. This is a critical distinction of the role and value of design – from design as a *noun*, to design as a *verb*.

This clarification as to the potential role of design has allowed the discipline to reposition itself from a downstream manufacturing activity to one which adds strategic is value to business. This union of design as process and business strategy is often referred to as design thinking: "a discipline that uses the designer's sensibility and methods to match people's needs with what is technically feasible and what business strategy can convert into customer value and market opportunities" (Brown 2008). The value that design thinking brings to an organisation is a different way of thinking, of framing situations and possibilities, doing things and tackling problems: essentially a cultural transformation of the way it undertakes its business.

As noted earlier, to remain competitive in this changing economic environment, manufacturers require a new mindset – shifting from a focus on operational efficiency to a way of thinking that allows them to explore new futures and opportunities. Adopting a design thinking mindset (not to be confused with what we know as "design as a noun") allows manufacturers to consider possible alternative futures.

> *"We can't solve problems by using the same kind of thinking we used when we created them"* (Albert Einstein)

However getting manufacturing firms to adopt such a shift in mindset is a challenge within itself. This topic is outside of the scope of this paper, however it should be highlighted that there are several program in place to build design thinking capabilities within firms. The more difficult challenge is once firms have understood that their mindset is stifling the type of innovation required in current economic circumstance, how do you best support and enable this new capability.

Type of innovation	Ability of Australian manufacturers	Value outcomes	Available strategies
Technology			
e.g. nanotechnology, social media, biotechnology	Strong	Innovations that CREATE VALUE	Technology based R&D
Efficiency			
e.g. operational, engineering, financial systems, lean manufacturing	Strong		Efficiency based business transformation frameworks
Offering Design			
e.g. user-centred, behaviour-changing, marketing	Weak		Design led innovation
Business Model			
e.g. stakeholders, distribution, partnerships, revenue models, branding	Weak	Innovations that CAPTURE VALUE	
Effectiveness Improving			
e.g. provision of tailored products and customer-focussed solutions	Weak		

Source: Bucolo S, King P, Australian Design Integration Network, 2014, Design for manufacturing competitiveness, p. 11 (adapted from Roos G, 2011 – Manufacturing into the future).

Moving from design thinking to design led innovation

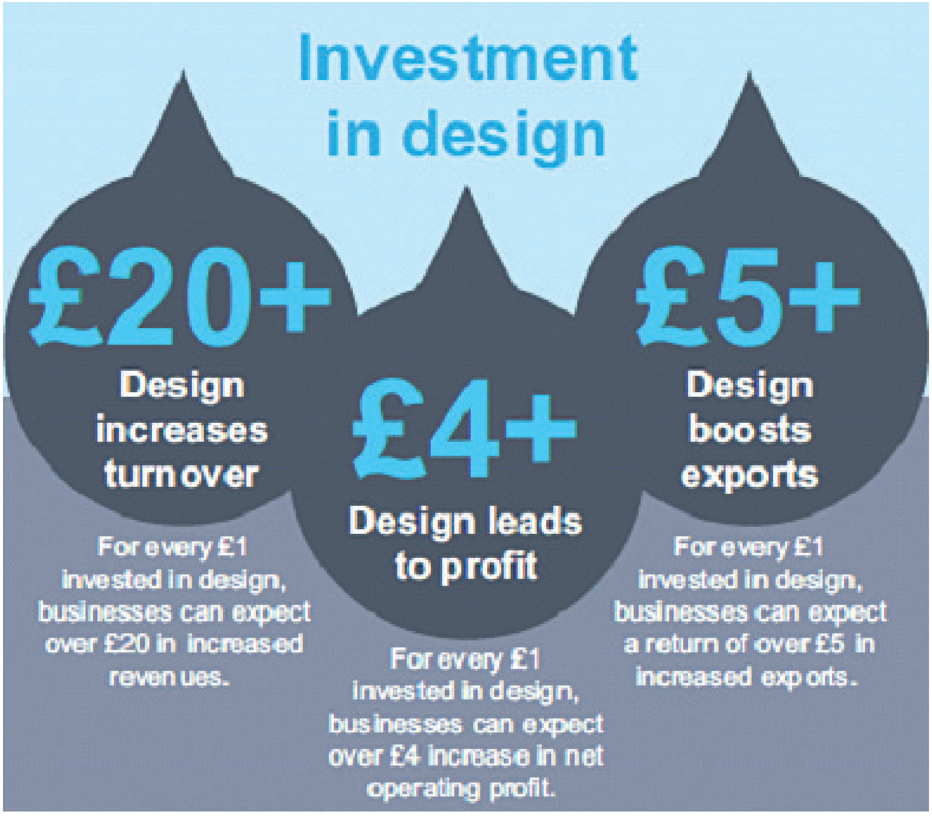
In order to achieve global competitiveness, manufacturing firms need to balance design for creation (making things) with designing for value capture (business model design). A greater level of business sophistication is required to make this happen, design led innovation provides this capability.

Therefore the real opportunity to transform the manufacturing sector lies in the application of design to an entire business strategy, which is referred to as Design Led Innovation (DLI). The term 'design-led' is defined by Bucolo and Matthews (2011) as the tools and approaches which enable design thinking to be embedded as a cultural transformation within a business. Being design-led requires a company to have a vision for top line growth within their business, which is based on deep customer insights and expanded through customer and stakeholder engagements, with the outcomes being mapped to all aspects of the business to enable the vision to be achieved.

DLI builds upon the practices and values that design plays in new product development activities, but extends this to focus on how a firm can integrate diverse sources of knowledge and insights to generate new business models which embody new products and services. DLI is a whole of business strategy, encompassing whole of supply chain to improve productivity and competitiveness. DLI focuses on the role of the customer (B2C and B2B), emphasising marketing, branding and networking skills to produce diverse and customised solutions.

When organisations design for creation their innovation is typically limited to technology. Organisations operating in this mode understand their customers' needs and their current market, have good operational efficiency and are locally competitive. However, by concentrating on improving the product (the 'what'), organisations are naturally focused on what they know, rather than what they do not yet know. Paradoxically, this focus on the 'known' is inherently retrospective; it is the opposite of innovative. When innovation is limited to product design and improvements to technology, organisations leave themselves open to a greater risk of obsolescence – of their competitors speedily developing a better, more cost-effective product.

As the table above describes, the DLI process involves a partnering of design for creation (making things) with designing for value capture (business model design), with the use of non-technological innovation such as management capability and business model innovation as key mechanisms to increase firm competitiveness.



Source UK Design Council

There is sufficient evidence to suggest that companies who use design in their business perform better economically in the marketplace and to indicate the positive contribution of design to both firms and the broader economy. The UK Design Demand 2012 program review (http://www.designcouncil.org.uk/) indicated that:

- Every £100 a design alert business spends on design increases turnover by £225.
- On average, design alert businesses increase their market share by 6.3% through using design.
- Shares in design-led businesses outperform key stock market indices by 200%.
- Businesses that see design as integral don't need to compete on price as much as others. Where design is integral, less than half of businesses compete mainly on price, compared to two thirds of those who don't use design.
- 51 per cent of Queen's Award for Export Achievement winners in 2002 directly attributed overseas sales success to their investment in design.
- Over 90 per cent found that design was valued by their international customers and 86 per cent indicated that design helps them to compete internationally.

This evidence is supported by programs undertaken in several nations. Much of this work focuses on European and Asian nations. Specific reported programs and examples are highlighted below (and outlined in Appendix 1):

- Between 2002 and 2005, the Finnish government invested 30 million Euros in design research and development in Finland.
- Other countries such as Spain and the Netherlands are expanding their design policy focus to gain competitive advantages.
- Similarly, design capability is being nurtured and developed to create competitive advantages across industries in the Asia-Pacific regions, where countries that historically based their economies on mass production now recognise that design is key to product and service differentiation, Japan, Taiwan, South Korea, and China in particular.

The outcome likely to prevail will depend profoundly on how societies, and especially policy makers and leaders respond.

- New Zealand has achieved proven economic benefit from programs in "Better by Design".
- The Design Singapore Council is focused on Singapore becoming a hub for design, and Singapore introduced a 250% Productivity and Innovation Credit (PIC) for Investments in Design in their 2010 budget.

Australian manufacturing and design led innovation

Australia is a laggard in both the adoption and level of support being provided to firms to build Design Led Innovation capability. However we have some champions, but more needs to be done.

In a recent study by Bucolo and King (2014), a small number of Australian firms have been identified as Design Led Innovation champions and have unique characteristics which underpin their innovation. Within this study the voices of industry have been used to identify that effective implementation of DLI involves to the application of five key principles which include:

- **Clarity of purpose:** Organisations need to have a clear purpose which is communicated openly, internally and externally, to ensure cultural alignment.
- **Become your market:** Organisation need to immerse themselves in the world of their customers and customer's customers and stakeholders to achieve key competitive insights resulting in opportunities for market disruption.
- **Be the disruptor:** In order to be globally competitive, organisations need to create business models that envisage future markets and services, as well as future products.
- **Integrated business model:** Organisations that innovate through integration along the value chain will be globally competitive.
- **Own the change experience:** Organisation need to be dynamic, agile and flexible and embrace change in order to remain relevant in the face of fierce global competition.

Successful implementation of DLI also requires firms to possess a number of skill sets, including strong managerial capabilities and the combination of business and science and technology-based expertise. These will contribute to the future skills which underpin a future manufacturing workforce. The importance of management capability in the adoption of DLI is a potential challenge for manufacturing firms, as recent studies have identified a number of gaps in Australia's management performance.

A number of design based programs have emerged in recent years across the globe identifying the need to adopt this capability to retain international competitiveness. However more needs to be undertaken to scale this across the sector. This will require more than building design thinking capability, but to ensure firms are supported with the necessary structural and cultural adoption mechanisms which a design led innovation approach affords.

As noted by a participant within the study by Bucolo and King:

> *Brace yourself re-jig your brain for a level of open-mindedness that even if you think you are open-minded, you are probably not open minded enough to get it. So brace yourself to be uncomfortable but stick with it and be a believer – you may not get there you know but brace yourself to give it a go. (RME)*

Acknowledgement

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Manufacturing 2030: Getting the questions right on work and skills

John Buchanan, Garima Verma and Serena Yu

Abstract

The better management of the flows of labour is the key employment issue for the future of Australian manufacturing. Developing capability in the domains of engineering, logistics/material handling, business professionals and customer service will be vital if a manufacturing sector of any scale is to flourish. Deepening the pool of labour skilled in these broadly defined vocations will improve flows into and out of manufacturing and can deepen the capacity of enterprises and individuals to adapt to changing circumstances between now and 2030. When conceived in this way the challenge is not: ‘how can we help manufacturing?’ Instead, the key issue is how can all players contribute to building up the adaptive capacity of firms and individuals to ensure all have the best chance of capitalising on new opportunities as soon as they emerge – in manufacturing or elsewhere?

Where are we coming from?

It is well known that Australian manufacturing is experiencing major upheavals. This is a problem being experienced by nearly all advanced industrialised economies. As Table 1 shows, over the last decade manufacturing employment has fallen by between 20 and 25 percent in countries like the Netherlands (-24.3%), the UK (-24.1%), Canada (-22.0%) and France (-21.6%). In this context, the fall in Australian manufacturing employment of 9.5 percent is relatively modest.

Table 1: Changes in levels of manufacturing employment, select countries, 2002 - 2012

Country	Percentage change in manufacturing employment 2002 – 2012 (%)
Netherlands	-24.3
UK	-24.1
Canada	-22.0
France	-21.6
New Zealand	-16.9
USA	-14.8
Australia	-9.5
Germany	-6.9
Korea (Republic of)	-3.2

Source: U.S. Bureau of Labor Statistics 2013, International Comparisons of Annual Labour Force statistics, 1970-2012, Table 2-4.

This development has not been uniform for all parts of the sector or all occupations within it. As Table 2 shows, employment levels in some sub-sectors have grown. Significant growth has occurred in Beverage and Tobacco Product Manufacturing (+20%), Primary metal and metal product manufacturing (+14.2%) and Food product manufacturing (+12.1%). More sectors, however, have experienced losses. In proportionate terms the largest have been in Pulp and paper products (-45.4%), Textiles, clothing and footwear (-41.1%) and Fabricated metal products (-40.0%).

Table 2: Changes in employment level within manufacturing subsectors, percent, Australia 2012-13 compared to 2002-03

Industry subsect	Percentage change (%)
Beverage and Tobacco Product Manufacturing	+20.0
Primary metal and metal product manufacturing	+14.2
Food product manufacturing	+12.1
Machinery and equipment manufacturing	+8.9
Petroleum and coal product manufacturing	+3.1
Basic chemical and chemical product manufacturing	-5.6
Non-metallic mineral product manufacturing	-22.0
Printing etc	-22.6
Furniture and other manufacturing	-26.0
Transport equipment manufacturing	-28.8
Polymer product and rubber product manufacturing	-29.9
Wood product manufacturing	-33.3
Fabricated metal product manufacturing	-40.0
Textiles, Clothing, Leather and Footwear	-41.1
Pulp, Paper and Converted Paper product manufacturing	-45.4

Source: ABS, Labour Force, Australia, detailed, quarterly, original (cat no. 6291.0.55.003), four quarter average. Manufacturing nfc is not included in the table. These statistics have been taken from AWPA Manufacturing Workforce Study April 2014, pages 78, 143

Trends in the occupational composition of employment have been just as differentiated. The key developments are summarised in Table 3. Between 1986 and 2013 the proportion of technical, trades, machine operators and labourers fell from 72 to 59 percent of employment. The net growth in white collar employment was amongst managers and professionals.

Table 3: Changing occupational shares within manufacturing, Australia, 1986, 1996, 2006 and 2013

Year (August)	ANZSCO basic disaggregations 'Production'/'White collar'							'Production'/'White collar'	
	Managers	Professionals	Technicians + trade workers	Machinery operators and drivers	Labourers	Clerical + Administrative workers	Sales	Intermediate technical + blue collar workers	White collar workers
1986	7	5	[32]	19	21	[12]	[4]	72	28
1996	9	7	29	18	22	10	4	69	31
2006	13	8	28	14	20	11	5	62	38
2013	15	9	28	13	18	10	6	59	41
Change	**+8**	**+4**	**[-4]**	**-6**	**-3**	**[-2]**	**[+2]**	**-13**	**+13**

Source: ABS Labour Force Survey, accessed via Super Data Hub

Note: A new occupational classification system applied from August 1996 – a shift from ASCO to ANZSCO. The following occupational categories were considered a continuous time series: Managers, Professionals, Labourers, Clerks/Clerical and Administrative workers, and Plant and Machine Operators/ Machine Operators and Drivers and Labourers. Number in square brackets are regarded as at best indicative and not strictly directly comparable to the later categories.

What are the key characteristics of the current situation?

It is unhelpful to conceive of manufacturing as one distinct, relatively self-contained sector: it is differentiated internally and has extensive linkages with many other parts of the labour market. While the sector is commonly broken down (ie disaggregated) into 15 basic sub-categories, the top four account for the bulk of employment. They constitute very quite distinct domains of economic practice and in thinking about the future it is often more appropriate to consider their past's and future's independently. As Figure 1 shows the largest sub-sectors are involved in producing Food products, Machinery and equipment, Primary metal and metal products and Transport equipment.

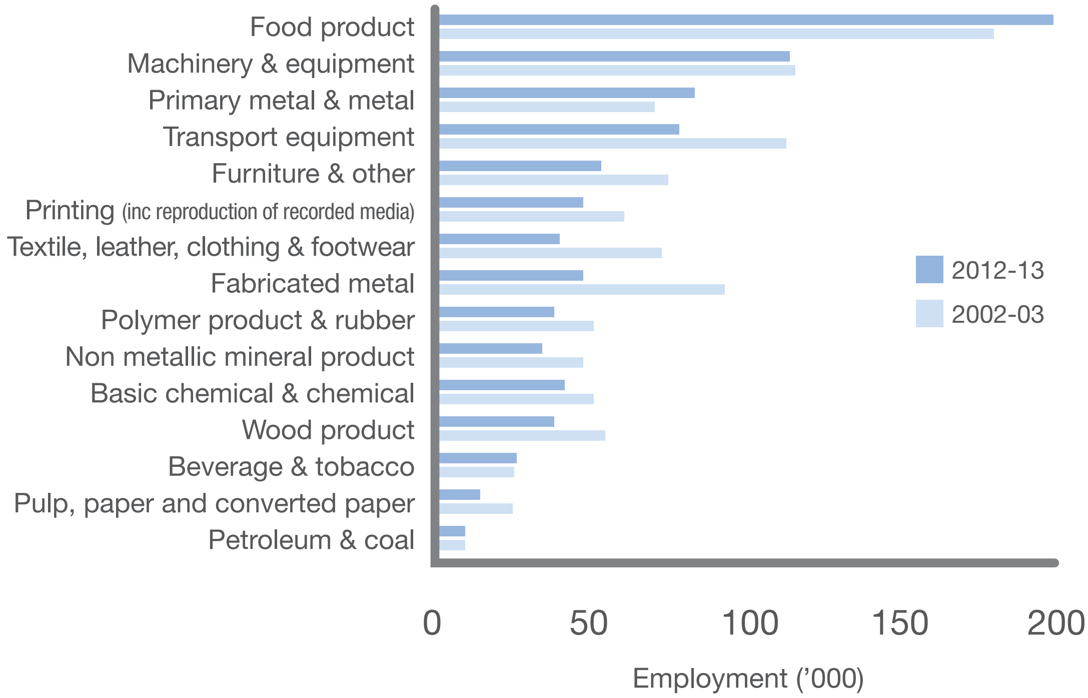

Figure 1: Employment in manufacturing by subsector, 2002 03 and 2012 13

Source: ABS, Labour Force, Australia, detailed, quarterly, original (cat no. 6291.0.55.003), four quarter average. Manufacturing nfc is not included in the table. Figure taken from AWPA Manufacturing Workforce Study April 2014, page 78.

The industry draws on and contributes to distinct labour markets across the economy. The iconic Metal Fitter and Machinist has long been recognised as playing this role. In 2013 there were 124,200 such skilled workers, but only 32 percent of them worked in manufacturing. Since 1991 the total number of such workers has increased by approximately 30,000 but the proportion of them working in manufacturing has declined by over 24 percentage points. Table 4 provides precise details.

Table 4: Metal Fitters and Machinists, total in all industries, number in manufacturing and proportion of the trade employed in manufacturing

	1991	2013
Metal fitters and machinists working across all industries	92'532	124,200
- Number working manufacturing	51,910	39,744
- Proportion working in manufacturing	56.1%	32.0%

Sources: Data for 1991 derived from the ABS Household and Population Census of that year prepared by Ian Watson. The material was originally reported in 'Overview of key findings from ABS Statistics on the Metal and Engineering Labour Market' prepared for the National Metal and Engineering Training Board, Friday 18 March 1994 – speaking notes prepared by John Buchanan, Gabrielle Sullivan and Ian Watson of the Australian Centre for Industrial Relations Research and Training (ACIRRT), University of Sydney. Data for 2013 is taken from material reported in AWPA Manufacturing Workforce Study April 2014 Appendix E: Occupational employment numbers. The original data were obtained from ABS, Labour Force Survey, Australia, 2013, detailed quarterly, Cat No 6291.0.55.003 prepared as a custom request for AWAP by the ABS.

The connections between manufacturing and other sectors in not confined to the well defined occupational labour markets for the trades. Data recently released by AWPA (2014) allows for a more nuanced understanding of both the occupational character of the manufacturing sector's workforce and, most importantly, what proportion of various occupations is employed in manufacturing. Key statistics are summarised in Table 5. Because of the disaggregated nature of this material it is possible to report around more meaningful categories to understand the sector's occupational profile and how it as an industry connects with labour markets else-where.

The key categories of work are:

- Management and business professionals
- The professional engineering, scientific, technician and trades workforce
- Logistics and materials processing workers
- Customer service workers.

In only one of these four categories (logistics and materials processing) does the majority of an occupation work in manufacturing.

These data also clarifies with precision that the growth in professional employment reported in Table 3 has been among business professionals. Professional engineers and scientists collectively account for under 30,000 workers in the sector. This is smaller than the sector's sales workforce (40,400). There are more accountants (10,900) than there are Professional industrial, production and mechanical engineers (10,200). Traditionally lower skilled workers have been classified by the ABS as 'machine operators ' or 'labourers'. Closer inspection of the largest sub-categories reveals that in manufacturing they are more accurately characterised as logistics and/or materials handling workers. Some of the largest categories of non-trades, blue collar workers are Packers (23,700), Stores workers (19,400) and forklift drivers (17,400).

Table 5: Top five two digit occupations in key vocational domains, numbers and proportion of the two digit occupation employed in Manufacturing, Australia, 2013

Senior managers + business professionals			Technical professional and trades level						Materials processing + Logistics			Customer service		
			Professional Engineers +Scientists			Technician/Trades worker								
	Presence in manufacturing			Presence in manufacturing			Presence in manufacturing			Presence in manufacturing			Presence in manufacturing	
	Number ('000)	%		Number ('000)	%		Number ('000)	%		Number ('000)	%		Number ('000)	%
Production managers	37.0	64.9	Industrial, Production + Tech Engineers	('000)	34.8	Structural steel and Welding trades	45.2	56.0	Food + Drink Factory Workers	28.4	89.8	Sales Assistants	25.1	4.8
Advertising and sales managers	22.4	17.0	Chemical, food + wine scientists	4.7	48.8	Meal Fitters and Machinists	37.0	31.1	Packers	23.7	43.1	Sales represent-atives	16.6	17.5
Manufacturers	18.1	87.9	Software + appliance programmers	3.9	4.4	Cabinet makers	20.7	81.7	Product assemblers	23.3	79.3			
Accountants	9.5	5.7	Electronic engineers	3.4	40.6	Bakers + pastry cooks	15.0	15.0	Storepersons	19.4	16.0			
CEOs + M'ging Directors	7.7	12.6	Electrical engineers	3.3	22.4	Carpenters and Joiners	13.7	10.4	Engineering Production System Workers	19.2	81.6			
Sub -total/ unweighted average	**94.7**	**37.6**		**27.7**	**30.2**		**131.6**	**38.8**		**114**	**62**		**41.7**	**11.2**

Source: This table has been prepared from material reported in AWPA Manufacturing Workforce Study April 201 4Appendix E: Occupational employment numbers. The original data were obtained from ABS, Labour Force Survey, Australia, 2013, detailed quarterly, Cat No 6291.0.55.003 prepared as a custom request for AWAP by the ABS.

Recently released data on labour flows over the last decade reveals most workers in manufacturing move within occupational streams – not between them. Serena Yu and colleagues (2011, 2012a, 2012b) have examined flows learning and labour amongst professional/managerial, trades/technician and blue collar workers below trades level. Using data on the same group of workers over a 10 year period they have assessed the degree to which pathways in awards and qualification arrangements align with movements of people. By and large they found very limited vertical progression. Overwhelmingly people stay in the three streams studied.

What's on the horizon?

The Australian Workforce and Productivity Agency (AWAP) has identified four potential scenarios for the Australian labour market and how manufacturing is likely to contribute to and be affected by them over the coming decade. The key features of these are summarised in Appendix A. The four Scenarios are described as: 'The long boom', 'Smart Recovery', 'Terms of Trade Shock' and 'Ring of Fire'. Under the first three manufacturing employment is assumed to fall by around 1 percent per annum. Under the latter, to increase by between 2 and 3 percent per annum. The energy company, Shell, has been more forthright in its assessment of the future. In making projections to 2050 it identified a large 'zone of uncertainty' over the coming decades (Shell 2011). It defines this zone as providing for either 'extraordinary opportunity or extraordinary misery' (See Appendix B). The outcome likely to prevail will depend profoundly on how societies, and especially policy makers and leaders respond. It sees two basic scenarios – 'scramble' or 'blue-prints'. Well organised responses will help achieve opportunities. The scramble scenario will make avoiding unnecessary suffering difficult.

What are the implications for employment and skills (ie workforce development) given the above analysis?

The labour market is more like a river than a lake. And it is not one big, steady current, but rather more like a network of streams comprised of segmented but connected flows - much like a New Zealand braided river or a delta like that of the Nile or Ganges. For many workers their movement through the labour market is like a flow within a limited number of loosely connected streams. We call these vocational streams. As we note in Appendix C, a vocation emerges from fields of practice where there are capabilities in commonalities; for example, the commonalities between stores work, packing work and product assembly are such that that the work can be conceived as different aspects of a logistics flow. A vocation groups together related clusters of knowledge and skills that allow individuals to progress by specialising within a field of practice, by moving laterally into linked occupations, or by moving onto higher studies.

A vocational stream consists of linked occupations within broad fields of practice, and in turn, each occupation leads to a number of jobs. That is, within a stream (eg.logistics) there are more specialised occupations that allow for ease of labour mobility for people with recognised skills, and equally exclusion of those without it (eg. Forklift driving can undertaken by someone with good logistics capabilities but such individuals usually need a special licence to undertake this specific type of work). Even within tightly defined occupations, the final configuration of activity varies between jobs. Somebody involved in a logistics flow in Food production manufacturing would engage in quite different work to one in Machinery and equipment manufacturing.

This way of thinking is not of mere academic interest. Currently much policy about education and work assumes upward progression based on metaphorical pathways defined in fairly linear terms. As Yu et al have noted such pathways, however, rarely correspond with people's actual trajectories through education and work. In preparing for the future it is vital to engage with this reality of often tacitly defined vocational streams – within as well as beyond manufacturing.

The AWPA and Shell scenarios highlight that change of some kind – most likely quite dramatic – is coming. The key questions are:

(a) How can manufacturing help people adapt successfully to whatever comes to pass?

(b) How can approaches to workforce development in other sectors nurture workers with capabilities relevant to manufacturers when mobilising to seize opportunities for growth or new niche markets as soon as they emerge?

The data reported above highlighted that manufacturing does not rely much on labour that is purely 'manufacturing specific'. Instead it needs people with capabilities to work well in the domains of:

- Engineering
- Logistics and materials handling
- Business professionals
- Customer service.

The development of workers with capability in these vocational streams requires active involvement of employers in the provision of learning on the job. It is very difficult for workers to be productive and adaptable until they have learnt how to apply class room knowledge in a work setting. Historically, a large proportion of skilled blue collar workers involved in manufacturing acquired their capabilities through the apprenticeship model of learning.

There is a need to identify new ways of deepening capability by a combination of practical and conceptually based learning relevant to today's world. In the last deep crisis of the early 1980s the institutional form of 'group training' emerged to help revitalise the apprenticeship model. In parts of the agricultural sector, farmers and employers with a common interest in workers with broad 'rural operations' expertise, have coordinated their labour demand calendars to ensure they can offer workers year round employment supported by the acquisition of a recognised qualification (ie a Certificate III in Rural Operations). Is it time to rethink the role of labour hire in manufacturing so that it can support better risk management for all the industry?

There is also an opportunity to rethink VET in schools. Instead of operating as a 'bolt on' onto the standard schools model there are instances where a principled concern with vocational relevance can be integrated with all parts of the school curriculum. In some advanced high schools maths and science classes are actively connected with local engineering employers. Customer service does not just have to be about retail and hospitality – it can be linked to sales and marketing activities in a wide range of sectors including manufacturing.

Given the importance of innovation, there would be a major benefit for manufacturers taking the lead in developing and spreading new forms of work integrated learning. Innovation is not just found in R+D laboratories – it also often emerges as a result of the accumulation of lots of small everyday life changes. Building better work integrated learning in the sector could play a vital role in fostering a more systematic approach to reflection on the job – the prerequisite for innovation.

Building communities of trust amongst employers, education providers and employee representatives is a vital pre-condition for success in this domain. The Industry Skills Council offers the perfect place to devise initiatives to improve approaches to learning in, for and about the sector and the vocational streams which it draws on and to which it contributes.

Conclusion

The better management of the flows of labour is the key employment issue for the future of Australian manufacturing. Developing capability in the domains of engineering, logistics/material handling, business professionals and customer service will be vital if a manufacturing sector of any scale is to flourish. Deepening the pool of labour skilled in these broadly defined vocations will improve flows into and out of manufacturing and can deepen the capacity of enterprises and individuals to adapt to changing circumstances between now and 2030. When conceived in this way the challenge is not: 'how can we help manufacturing?' Instead, the key issue is how can all players contribute to building up the adaptive capacity of firms and individuals to ensure all have the best chance of capitalising on new opportunities as soon as they emerge – in manufacturing or elsewhere?

There is a need to identify new ways of deepening capability by a combination of practical and conceptually based learning relevant to today's world.

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Appendix 1: Professor Sam Bucolo

Appendix 1 – Design Led Innovation Reports

Many of these documents below are future oriented, based on customer insights and provide a basis for future investment in design-led innovation as a pathway for competitiveness and the development of new business models. These documents also look to frame design in terms of more than just design for aesthetic purposes.

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Appendix A: Professor John Buchanan

Extract from AWPA Manufacturing Workforce Study, April 2014 (page 129)

With a view to avoiding skills shortages, improving productivity and enhancing participation, AWPA has developed a suite of scenarios for Australia to 2025 as a basis for modelling Australia's workforce needs and developing policy to help meet those needs. The scenarios are not projections, nor are they based on past trends, but represent a range of possible futures for Australia that help us to plan for an uncertain world . The four scenarios are:

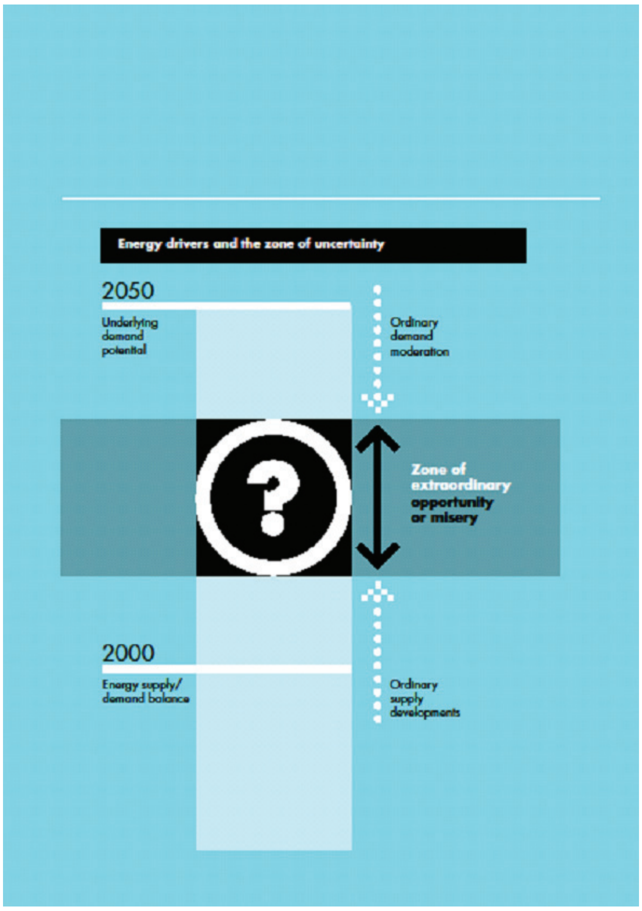
1. **The Long Boom:** The economy recovers from the financial uncertainty of 2012 and India and China drive the demand for Australian resources. Mining and construction continue to thrive in Australia. Industries like manufacturing, challenged by the high terms of trade, undertake structural adjustment. Average annual growth for manufacturing output and employment are 0.6 per cent and -1.5 per cent respectively.
2. **Smart Recovery:** A protracted European downturn and slowing growth in China and India create a drop in demand for Australian resources. As global growth resumes from 2014–15, the Australian economy looks to knowledge-based industries to drive growth, which leads to increased demand in technology-related skills. Average annual growth for manufacturing output and employment are 1.4 per cent and -1.3 per cent respectively.
3. **Terms of Trade Shock:** An oversupply of commodities creates a drop in commodity prices. Australia moves to a broad-based economy with internationally competitive businesses. The material content in many products is reduced through advanced engineering design, which in turn decreases worldwide demand for commodities. Small technologies and micro fabrication help drive the reestablishment of a viable Australian manufacturing sector based on technology and innovation. Giant 3D printers and robotics replace assembly lines. Average annual growth for manufacturing output and employment are 1.9 per cent and -1.0 per cent respectively.
4. **Ring of Fire:** In a context of natural disasters, global crises, political unrest and increased protectionism, the lower Australian dollar enable the strengthening of trade-exposed industry sectors. As global trade wanes, manufacturing employment and output grow at an average annual rate of 0.6 per cent and 2.4 per cent respectively.

Economic modelling against each of these four scenarios was undertaken by Deloitte Access Economics (DAE) to determine the skills demand for the economy into the future.

AWPA has taken the view that the Ring of Fire Scenario is a relative outlier in terms of workforce and qualifications outcomes for Australia in the future and should not be considered as a focus of analysis and planning. Figures for this scenario have still been provided in the report for completeness.

Appendix B - Extracted From Shell Energy Scenarios 2050

Energy drivers and the zone of uncertainty



Appendix C: Understanding flows of learning and labour: human capability, vocations and vocational streams

1. Key Concepts

This section outlines the key concepts of 'capabilities', 'vocations' and 'vocational streams' we have developed in a series of linked papers and projects (Wheelahan et al, forthcoming; Yu et al, 2012; Wheelahan & Moodie, 2011). It is important that the concepts we are using are clear given that the project is seeking to explore the potential for new ways of supporting skills development. The project is part of a process that is developing a new conceptual language for describing the links between education and work in Australia and it is essential that these concepts are clearly delineated.

1.1. The Capabilities Approach to Work

The capabilities approach focuses on what people are able to 'be and do' and the necessary resources and social arrangements that are needed to achieve this (Nussbaum 2000, 2011; Sen 1999). In thinking about work, the capabilities approach asks about the broad ranging knowledge, skills and attributes that individuals need to be skilful at work, to progress in their careers and studies, and to participate in their communities and in civil society.

Capabilities shape the way individuals live their lives, exercise choice, and exercise autonomy, judgement and creativity at work. They are underpinned by individual, economic, social, cultural and environmental resources; that is, they are concerned with the skills and attributes people need to flourish in particular fields of activity. Capabilities are differentiated from employability skills or graduate attributes because they are not 'general' or 'generic'. For example, while there are some common foundation capabilities required of all workers, someone who undertakes care work will require different capabilities from those working in agriculture, finance or engineering. As an illustration, problem solving with a two year old in a crèche is quite different to problem solving in a science laboratory, as is communication. In a capabilities approach, the focus is on the development of the individual and on work, and consequently students need access to the knowledge, skills and capabilities so they can be creative problem solvers and exercise autonomy in their domain of activity – what we call vocational streams.

1.2. Vocations and Vocational Streams

A vocation emerges from fields of practice where there are commonalities; for example, the commonalities between aged care and disability care. A vocation groups together related clusters of knowledge and skills that allow individuals to progress by specialising within a field of practice, by moving laterally into linked occupations, or by moving onto higher studies.

A vocational stream consists of linked occupations within broad fields of practice, and in turn, each occupation leads to a number of jobs. That is, within a stream (eg. livestock farming) there are more specialised occupations that allow for ease of labour mobility for people with recognised skills, and equally exclusion of those without it (eg. animal technician, dairy farmer). Even within tightly defined occupations, the final configuration of activity varies between jobs. A technician looking after animal health on a dairy farm would engage in quite different work to one on a poultry farm.

There are significant benefits for the economy at large as well as for individuals having capabilities that allow them to move vertically and horizontally between and within vocational streams, rather than knowledge and skills for a specific job. In short, we define vocational streams as linked occupations within broad fields of practice where the focus is on the development of the person, the attributes they need and the knowledge and skills they require to work within a broadly defined domain (i.e. work space) that combines educational and occupational progression (Wheelahan et al. 2012; Yu et al. 2012).

1.3. The Capabilities Approach to Vocational Education and Training

The capabilities approach starts with the person and not specific skills, tasks or roles and asks about the capabilities that people need to achieve a range of outcomes. Education and training based on capabilities would focus on developing individuals in three domains:

The knowledge base of practice. This includes theoretical knowledge needed for the field of practice, but also for higher level study within the occupation;

The technical base of practice. This includes industry skills that transcend particular workplaces; and,

The attributes the person needs for that occupation or profession. This includes attributes such as ethical practice, but also effective communication skills, the capacity to work autonomously and in teams, creativity, information management and so forth. While these are sometimes described as generic, they are understood differently in different fields of practice and need to be developed within the context of specific disciplines and vocations.

Within this approach, qualifications would prepare students for a broad range of occupations within loosely defined vocational streams, support students to engage in occupational progression through a career, link occupational and educational progression, and adapt to meet new and emerging needs.

1.4. The Capabilities Approach, Labour Supply, Labour Demand and Labour Market Dynamics

The relationship between capabilities, vocations and vocational streams are presented in Figure A3.1. The vertical and horizontal components of Figure A3.1 can be taken as representing new ways of thinking about labour supply and labour demand.

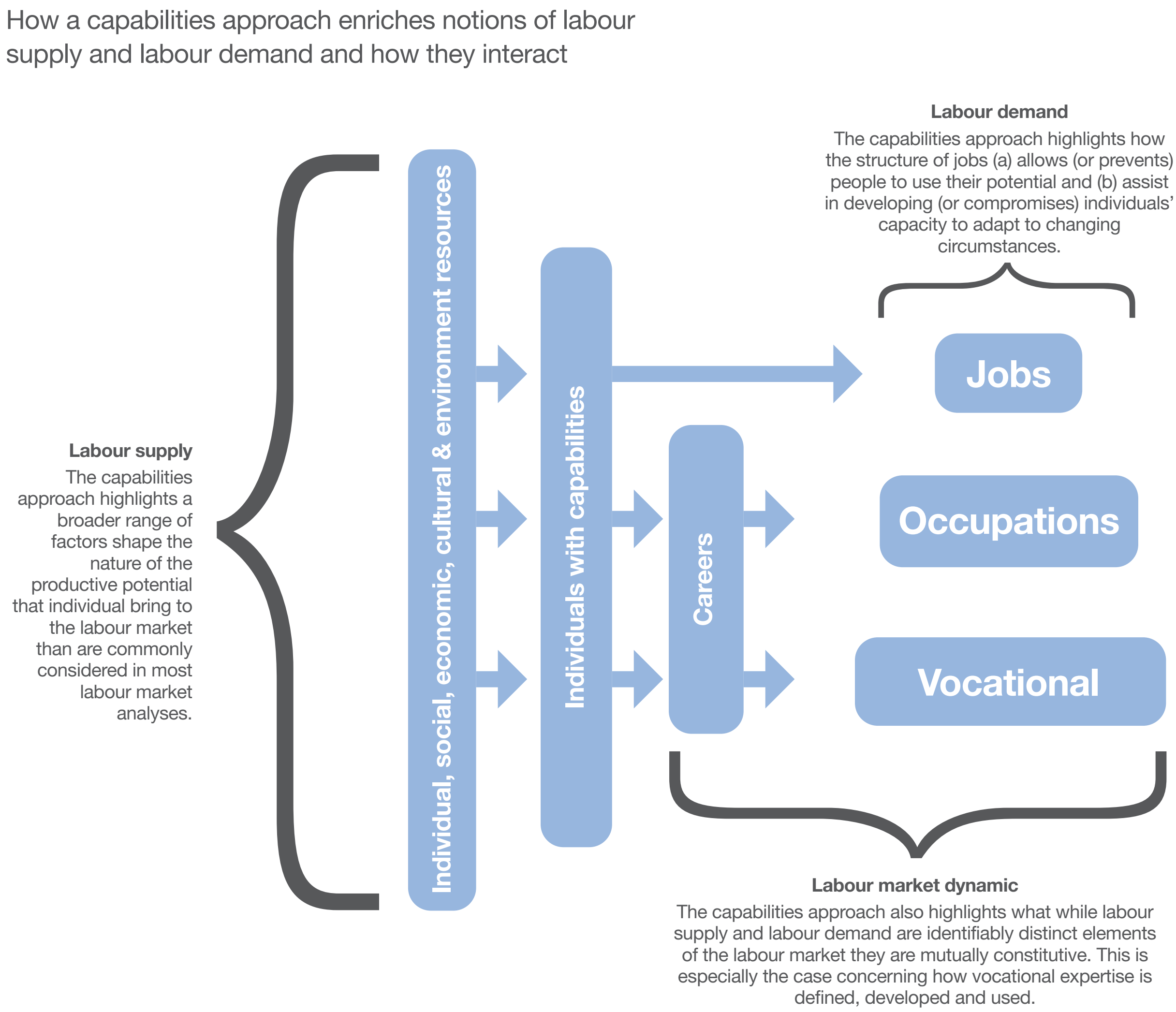
The supply of potentially available labour, especially its quality, is determined by:

- Access to resources. Individuals need broad capabilities in order to engage in vocational practices. These capabilities are underpinned by individual, economic, social, cultural and environmental resources. For example, individuals need access to health care, good food, basic education, transport, and networks of social support if they are to undertake education, go to work, become involved in their communities and so forth (Sen, 1999).
- Capabilities which include the fundamental abilities of all citizens that concern the capacity to flourish – or at least fit in – socially at work and in their broader communities, but also complex capabilities that allow individuals to integrate and synthesise knowledge, skills and attributes to exercise judgement and autonomy in their lives and at work (Winch 2010). The capacity to be skilled at work emerges from wide-ranging capabilities, and so capabilities will always be wider than those required just to undertake specific workplace tasks and roles.
- Careers. Over the course of their lives individuals, through their work, acquire specialised knowledge, technical capacities, intuitions, inclinations and reasoning associated with a distinct realm of practice such as nursing, engineering, agricultural work and financial services. The accumulation of this expertise constitutes careers. For some, a career can involve deepening expertise in a clearly defined occupational pathway (eg nursing). For others careers can involve moving across a number of vocational streams. For many it involves churning through low end work which, while varied, is rarely challenging in a skills sense. Careers of the latter type rarely involve the deepening of expertise in any domain and thereby limit the capacity of individuals to take on my difficult challenges and opportunities as circumstances in the labour market change.

The demand for labour is characterised by the sector's skills ecosystem, a cluster of skills in a particular region or industry which is shaped by the interdependencies of firms, markets and institutions (Buchanan et al, 2001). In particular, the demand for labour is shaped by the competitive nature of the product market, and institutional frameworks, but also the nature of skill formation (eg the use of apprenticeships), the structure of jobs (eg seasonal work), and the modes for engaging labour (eg casual or shift work).

This framework helps us to consider the relationship between education and work. While tertiary education should primarily prepare people for employment, in developing the capabilities for work, education will need to go beyond work. Rather than preparing people for specific jobs (and discrete workplace requirements) the emphasis will be on preparing people for vocational streams. This will help promote vertical and horizontal occupational progression and more opportunities for individuals. However, this can only occur when and if vocational streams are identified and vocational preparation ensures that students have the depth and breadth of knowledge and skills they need, and the personal attributes required for that vocational stream. We have found that the coherence of vocational streams is a direct function of how well social partners (employers, unions, industry leaders, government and educational institutions) work together.

Figure A3.1: The capabilities approach, labour supply, labour demand and labour market dynamics



1.5. Communities of Trust

The capabilities approach is a more open-ended way of thinking about work, qualifications and vocational preparation and it depends on building communities of trust which comprise those who have a 'stake' in the sector's workforce development. The key focus of the capabilities approach as we are using it is to focus on building communities of trust that can overcome low levels of trust where they exist (for example, over issues of resource allocation, the value of qualifications, and other competing interests) and disconnection between vocational education and work. Communities of trust would work to establish broad workforce development strategies that include identifying emerging occupations within vocational streams, and developing the education and training programs that are needed to support those occupations.

Confidence in qualifications for example is greater when defined communities of trust have played a role in developing standards and accrediting qualifications and where qualifications are supported by systems of certification and quality assurance. Communities of trust include professional and occupational bodies, employer bodies and unions, skills councils, recognised industry leaders, employers and educational institutions, as well as appropriate government bodies. Another term which may be helpful is to refer to 'social partners' which comprises all these key stakeholders. Social partners may have higher or lower levels of trust, but they are the starting point for building communities of trust. Communities of trust do not have to (and will not) agree on all things at all times, but their debates are usually resolved and the outcomes are usually better because this is how knowledge and skills are developed and identified for different occupations.

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