Industry 4.0

Overview Report

This report is an overview of Industry 4.0 produced by the ADPG – Next Generation group and looks at the impact of Industry 4.0 from a procurement and supply chain perspective.

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EXECUTIVE SUMMARY

Industry 4.0 is a vision for the next paradigm shift in manufacturing and it is anticipated to add approx. £10 trillion to the global economy by 2030. At its core, it is about generating new data insights to identify innovative business opportunities and efficiencies that are able to act as competitive differentiators for an organisation. By applying digital technologies to physical production processes (and vice versa) within a connected network of internal and external dimension, Industry 4.0 aims to create smart cyber-physical systems that can dynamically react to real world changes and optimise production flows. Sophisticated data analytics, artificial intelligence and a number of other supporting digital technologies make it possible for the wealth of new data generated by these connected smart cyber-physical systems to be converted into highly sought insight that have the potential to significantly transform business strategies and organisational long term direction.

For Procurement and Supply Chain operations, Industry 4.0 is set to usher in the possibility of hitherto unprecedented levels of supply chain interconnectivity and dynamic data exchange. New digital technologies will assist Buyers to act on that real time data to make more informed sourcing and contract management decisions, increased responsiveness to changeable supply chain factors.

The structure and responsibilities of the Procurement and Supply Chain function will need to change under effective Industry 4.0 implementation. Increased automation and computer augmentation will threaten transactional roles but as the key interface between internal and external value chains, the function will have to take a lead role in establishing and maintaining the collaborative relationships with technology and supply chain partners needed to ensure continued access to enabling technologies and supply chain data sources. Procurement and Supply Chain will need to take on a strategic contributor role within the organisation and use the key skills currently lacked by machines (e.g. creativity, complex problem solving and Emotional Intelligence) to develop new value propositions so that the objectives of Industry 4.0 can be met.

The key barriers to Industry 4.0 adoption are:

- Ensuring cyber security measures are sufficient to protect organisations against the increasing cyber threat posed by holistically connected supply networks;
- A shortage of key digital skills;
- Issues finding the right supply partners; and
- Conceptual issues over the technologies themselves and their purported benefits.

Due to the particular sensitivity of both physical and information assets in the Aerospace and Defence industry, ensuring the cyber security of interconnected systems is an acute problem in the industry to the widespread adoption of integrative digital technologies such as Cloud Computing and the Internet of Things. Applications are however being found; particularly in the field of Maintenance, Repair and Overhaul fault diagnostics and Aerospace and Defence is leading markets in Additive Manufacturing where the benefits generated from the ability to rapidly print small batch, complex, engineered parts is well suited to its bespoke contracts.

Industry 4.0 offers clear benefits for early adopters but will eventually become the norm across the manufacturing sector. At some future point it is considered that adopting it will therefore become a means of survival, not just as a source of competitive advantage. Manufacturers in Aerospace and Defence will need to find ways to adapt to an interconnected digital future to stay competitive and avoid obsolescence issues as conventional methods and technologies are phased out; a process which strategic Procurement and Supply Chain professionals will have a significant role in delivering.

Industry 4.0

TODAY

TOMORROW

Original diagram

PART 1

# OVERVIEW

1.0 WHAT IS INDUSTRY 4.0?

Industry 4.0 is a concept used to signify the next step change in the manufacturing sector. It denotes the change in manufacturing processes caused by (1) the application of a number of new digital technologies to conventional manufacturing processes and (2) the introduction of new production methods which can only be enabled by digital means. The effect of Industry 4.0 is anticipated to have a revolutionary change on existing value chains and business models.

Industry 4.0 is driven by four 'disruptions' (Baur & Wee, 2015):

1. The exponential rise in data volumes, computational power and connectivity;

2. The emergence of analytics and business-intelligence capabilities;

3. New forms of human-machine interactions such as touch interfaces and augmented-reality systems; and

4. Improvements in transferring digital instructions to the physical world such as advanced robotics and 3D printing.

The above technologies have now reached a point where their reliability and cost make them commercially viable for industrial applications. As a result it is now possible to create 'SMART' factories by integrating an organisation's physical manufacturing processes with cyber control and automation systems and by extending connectivity with a multitude of other devices, both internal and external, to a manufacturing organisation. With these developments manufacturing is being ushered into a new fourth industrial revolution (Fig. 1), where existing value chains and business models are likely to require fundamental changes (Zhong, Xu, Klotz, & Newman, 2017) as operational and administrative processes are revolutionised and new innovative digital products and services are created.

Figure 1: The Four Industrial Revolutions (Roser. 2015)
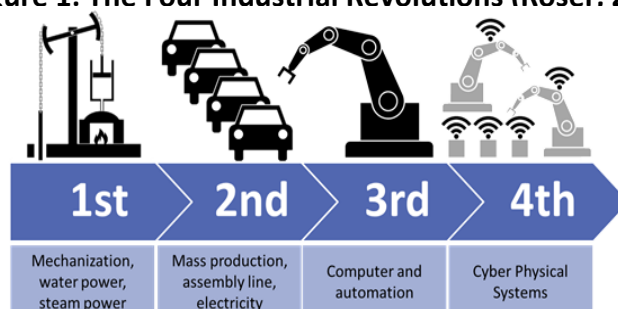
1.2   WHY IS IT IMPORTANT TO PROCUREMENT AND SUPPLY CHAIN?

Twenty-first century supply chains are world-wide inter-connected supply and demand networks with profound interdependencies and vulnerabilities. With product and information flows travelling between nodes in a variety of networks that link organisations, industries, markets and economies, they typically comprise vastly complex, inter-related operations. It is no longer accurate to consider processes to be linear and taking a siloed approach to understanding supply and demand would fundamentally misrepresent what is actually going on (Millar, 2015). The advent of Industry 4.0 offers the Procurement and Supply Chain Manager access to the information and technology needed to effectively manage risks and exploit opportunities in such complex and dynamic twenty-first century supply chains. It does this by providing unprecedented levels of access to dynamic, real-time information across their value chains and to digital tools which can assist in transforming data into valuable business insight. This will enable less reactive and more predictive decision making aided by developments in analytical solutions, allowing the real time, dynamic adjustment of supply chains as supply and demand conditions change within increasingly volatile global supply chains (Schrauf & Berttram, Industry 4.0: How digitization makes the supply chain more efficient, agile and customer-focused, 2016). It also offers key benefits in areas of efficiency, innovation, cost reduction, customer satisfaction and revenue growth and in conjunction with these, is set to transform the basis of global competition by dramatically increasing manufacturing agility without the trade-offs in quality, cost or time traditionally associated with such increases. Therefore, the end-to-end digitalization of value chains, products, services and business assets through advanced technologies which link the physical and cyber world is expected to have a revolutionary effect on global manufacturing operations and the effectiveness of Procurement and Supply Chain at managing twentieth-century supply chains.

According to a report conducted by The Hackett Group, "84% of procurement organizations believe that digital transformaton will fundamentally change the way their services are delivered over the next three to five years." (Mataverne, 2017). As manufacturers evolve and embrace Industry 4.0, new value propositions will be developed and data across value

chains and functions will be integrated to meet new business needs (Swali, 2017). With its unique position connecting internal and external value chains, Procurement and Supply Chains function will not only benefit from the Industry 4.0 technologies, it will also play a pivotal role in supporting the transition of manufacturers to the new business models and drive the evolution of traditional supply chains into the digitally connected, smart and highly efficient "supply chain ecosystems" (Schrauf & Berttram, Industry 4.0: How digitization makes the supply chain more efficient, agile and customer-focused, 2016). The Procurement and Supply Chain organisation will acquire new tools which will increase its capability to manage and exploit opportunities in modern supply chains and the roles, responsibilities and structures of the function will have to adapt to enable it to take on a more strategic role in delivering the Industry 4.0 objectives of the wider organisation. Operational Procurement responsibilites of the function will shrink by leveraging digital technologies to automate routine decisions and purchases, while the function will need to increase its strategic inputs by leveraging the newly available data to enhance key business decisions and establish the necessary information exchange networks with suppliers to (Swali, 2017):

1. Support the rest of the organisation in its Industry 4.0 transformation;
2. Manage the impact of digital technologies on the supply market; and
3. Continuously increase its value proposition. (Mataverne, 2017).

Table 1: Difference between Traditional and Integrated Ecosystem Supply Chains (PWC, 2014)

Supply Chain Factor	Traditional Supply Chain	Integrated Supply Chain Ecosystem
Transparency	Limited view of supply chain (typically no greater visibility than Tier 2)	Holistic view of supply chain with visibility across all tiers.
Communication	Information available on request but delayed as it moves linearly through each organisation in the supply chain.	Real time information readily available at all times to all organisations in the supply chain.
Collaboration	Widespread collaboration prevented due to lack of visibility of entire supply chain.	Holistic view enables organisations in the supply chain to see opportunities for collaboration more readily. Widespread collaboration naturally develops to grow the intrinsic value of the supply chain.
Flexibility to change	Information gets distorted as it flows linearly through the supply chain (like 'Chinese whispers') so the supply chain is less effective at responding to changes.	Information is widely available and known to be the single point of truth. The supply chain has relevant and accurate information, enabling it to respond effectively to change.
Responsiveness	Each supply chain organisation plans independently of the majority of other supply chain organsiations resulting in unsynchronised responses across multiple tiers, and supply delays.	Widely available, single point of truth information enables each organsiation to plan in full cogisance of the wider supply chain, allowing accurate real-time decision making.

1.3   BARRIERS TO CHANGE

By 2030, it is projected that Industry 4.0 will add approximately £10 trillion to the global economy and approximately £400 billion to the UK's (Geissbauer, Schrauf, Koch, & Kuge, 2014). PwC have indicated that over 50% of planned capital investment over the next 5 years will be in pursuit of Industry 4.0 objectives (Geissbauer, Schrauf, Koch, & Kuge, 2014).

Despite there being an industrial appetite to reap the benefits that are expected from Industry 4.0, significant barriers currently exist that have challenged its successful implementation. These barriers are particularly relevant to the UK manufacturing industry, which is currently trailing behind most other developed countries in the adoption of Industry 4.0 technologies and the necessary supporting infrastructure. While the UK is placed 11th on the EU ranking of digital readiness, the progress of other nations in overcoming the barriers to adoption demonstrate that solutions can be found to unlock the vast benefits on offer, and that a road map exists for effective implementation (Maier, et al., 2017).

The Made Smarter Review 2017 is a UK Government sponsored independent review of industrial digitalisation led by Professor Juergen Maier, CEO of Siemens UK. It has become a pillar of the UK's emerging Manufacturing Industrial Strategy. The results of its survey of UK manufacturing companies identified key areas where barriers were hindering the widespread adoption of Industry 4.0 (Fig. 2).

The Made Smarter Review identified that the five highest perceived barriers to be:

1. Cyber security;
2. Lack of technical skills to design and implement new systems;
3. Finding the right partners;
4.   Uncertainty over solutions working; and
5. Lack of awareness of new technical solutions.

Figure 2: Barriers to Industry 4.0 (Made Smarter Review, 2017)

1.3.1   Cyber Security

According to the Made Smarter Review, Cyber security was voted the greatest barrier to adoption of Industry 4.0. CISCO's 2017 cybersecurity report highlighted that the manufacturing industry is particularly vulnerable to cyber threats, due to:

- Its use of legacy equipment designed with little or no security in mind;

- Differences in IT and Operations technology;

- A lack of documentation outlining cyber responsibilities; and

- A systematic failure within the industry to conduct risk assessments.

Cyber security is already an issue for the manufacturing industry; 28% of companies surveyed by the Review reporting a loss of revenue in 2016 as a direct result of cyber-attacks, with the average loss being 14% of annual revenue. With Industry 4.0 aiming to achieve ever greater levels of integration between physical and cyber systems, both the probability and impact of cyber-attacks will grow if cyber defences are not robust enough to protect manufacturers from cyber threats. The rate of development of cyber security defences must match that of physical-cyber integration if manufacturers are to ensure they and the organisations to which they are connected can adequately counter new threats and are not left exposed to more frequent and/or severe attacks. However, this is not the current trend, as the Made Smarter Review also indicated that 46% of manufacturers have failed to increase their cyber security investment over the last two years despite taking steps towards implementing Industry 4.0.

Developing robust cyber security defences is an industry wide problem affecting all members of an end to end supply chain or network. In an Industry 4.0 connected supply chain or network unless the whole network is protected, weak links will leave other connected members vulnerable and open to attack. This is a particular problem within Aerospace and Defence due to the sensitive nature of information stored at certain nodes of the network and common use of small-medium enterprises which may lack an awareness of and means to achieve adequate cyber defences to combat present and future cyber threats.

1.3.2   Skills

The second highest barrier to Industry 4.0 adoption was the perceived lack of skills. To support Industry 4.0, workers will be required to redesign factories in the virtual world, implement new digital tools and applications and to interpret all the newly available data in "Data Scientist" roles. There is already an identified shortage of such digital skills in the UK and demand is only set to increase. Current forecasts suggest that 90% of all jobs will require digital skills within the next 20 years. In addition, as 65% of the workforce has left the educational system, the burden of upskilling/reskilling approximately 2 million people within the UK workforce to meet the forecast demand in the short to medium term will fall on employers (Maier, et al., 2017).

1.3.3   Finding the right partners

The successful implementation of Industry 4.0 will be dependent on effective collaboration between manufacturers and other companies, organisations, universities and associations. These relationships will not just contribute to effective organisational performance, they will underpin it. As such, the number of key and strategic relationships that the Procurement and Supply Chain function will be expected to manage will increase, and the current trend of focusing on value over purchase cost will be extended. Thankfully, other technological advances should enable traditional transactional purchasing to become ever more autonomous. This should enable Procurement and Supply Chain resource to be liberated from tactical cost saving transactions to be diverted towards the effective management of the more numerous strategic partnerships which will play a key role in value generation and an organisation's competitive advantage.

There are already a vast number of potential partners who could provide access to new digital technologies or provide support for the necessary enabling infrastructure required for Industry 4.0. This will only increase with the expected exponential adoption of digital technologies. Emphasis will need to be placed on using appropriate and comprehensive partnering criteria during the selection process as it is easier to collaborate with people that share your values, vision, and culture. The long term 'Strategic fit' of partners is also a key

consideration as over time and as technology based solutions evolve, there is a heightened risk that the business strategies and long term vision of each partner may become divergence as market conditions change. It is essential that corporate objectives of partners are aligned in the long term to ensure that meeting today's objectives does not prejudice meeting tomorrow's.

Even when suitable partners have been selected there are still challenges to effective collaboration, particularly with regards to the question of each partner's willingness to openly share information and how to move beyond the adverse relationships that are still pervasive in many industries. An ERIKS survey (Ohren, 2017) which looked at collaboration between organisations for progressive maintenance practices under Industry 4.0, identified that information sharing is not a natural behaviour. Of the organisations surveyed, 79% would only offer limited or non-disclosure information to OEMs and, even worse, 83% would offer only limited or zero disclosure to third party maintenance suppliers (Ohren, 2017).

In the Aerospace and Defence Sector, there is a reluctance to share information and adverse relationships between supply chain customers and buyers are not uncommon. One may find that acquisition proves to be an easier way to secure the necessary resources to support Industry 4.0 objectives within the sector (Geissbauer, Vedso, & Schrauf, A Strategist's Guide to Industry 4.0, 2016).

1.3.4 Uncertainty over solutions working

Manufacturing has taken its first steps toward industrial digitalisation but the outcome of having fully connected value chains which can stream and dynamically analyse real time supply and demand data remains highly conceptual and idealistic.

Based on current experience, there are challenges in making intra-organisational systems interoperable. These challenges increase as organisations look to extend these networks to include the organisation's physical assets as well as remote data sources external to the organisation itself. Standards can help to resolve interoperability issues however industrial

digitalisation is still a relatively new area and international standards have not yet been established.

Industry 4.0 links an organisation's competitive advantage to the effectiveness of its collaboration with value driving partners. While the technological challenge of linking independent systems is likely to be surmountable, the reluctance to increase dependency on other organisations, the current adversarial status of most relationships within Aerospace and Defence and the extreme cultural change required to establish and maintain the required level of collaboration all present further challenges to effective Industry 4.0 adoption. This can lead to a scepticism which itself becomes a barrier to the adoption of Industry 4.0. Essentially by questioning whether the ideal end state can feasibility be achieved and whether the outcome will yield the return on investment hoped for, the initial business case for investment is undermined.

Finally, current experience also indicates that while information management tools have greatly enhanced almost every aspect of business operations, technical problems including email and internet failures are the most stressful issue in office environments (Small business.co.uk, 2012). With greater digital integration, failures should also be expected as can the increased workplace stress that comes with a greater reliance on the reliability of technology.

1.3.5 Lack of awareness of new technical solutions

In the ERIKS survey, 72% of the engineers surveyed stated that they understood the potential of Industry 4.0, but 55% graded their knowledge as average or below. This suggests that the potential effects are better understood than the means of achieving them. Given the identified shortfall in skilled digital workers, the lack of understanding around how to get from the current state to the ideal Industry 4.0 end state is a clear problem. The situation is also complicated by the dynamic nature of technological advancement and the difficulties in accurately predicting what new products and services will be available in the future under exponential technological development. In addition, early adopters have found that the new levels of insight into their value chain have directly led to the

restructuring of their business models (Bruurmijn, 2016). It is therefore conceivable that, after designing, financing and implementing an Industry 4.0 infrastructure to support an organisation's future business aspirations, an organisation may find that the new insights yielded from Industry 4.0 may significantly alter its future direction and the infrastructure needed to support it.

1.3.2   Conclusion

Industry 4.0 has the potential to impart revolutionary change on the manufacturing industry however while approximately 70% of companies consider themselves prepared for the new technologies, only 5% believe they have achieved full implementation. There is clearly a long way to go before its full potential is unlocked, and organisations will face serious challenges getting to this junction (Ohren, 2017).

Cyber security is currently perceived as the greatest barrier to adoption (Maier, et al., 2017). However, being itself an Industry 4.0 technology, cyber defences should develop at a commensurate rate as other Industry 4.0 technologies driven by the demand for countermeasures to combat the growing threats caused by increased cyber-physical and value chain connectivity.

The present (and forecasted) lack of digital skills in the workplace is also a current barrier. The effective implementation of Industry 4.0 will require clearly defined strategies governing how organisations develop these skills and how they will establish and manage the necessary collaborative partnerships between industry, academia and research bodes.

In the long term, organisations appear to have a good understanding of the potential of Industry 4.0 but there remains scepticism over their whether the desired end state can ever be achieved. This limits the ability to generate a consistent business case to underpin investment in the necessary enabling IT infrastructure to support Industry 4.0. Further, a recognition of the level of dependency on external partners; the scale of the cultural change needed to move from adversarial to collaborative relationships and whether full value chain interoperability will ever be achieved (despite technical feasibility), breed uncertainty over whether the cost and effort associated with implementing Industry 4.0 may be too high

(Ostdick, 2017). These factors hint at a limited, piecemeal adoption of Industry 4.0 as uncertainty is resolved and individual business cases can be made, with greater surety, to justify the investment needed.
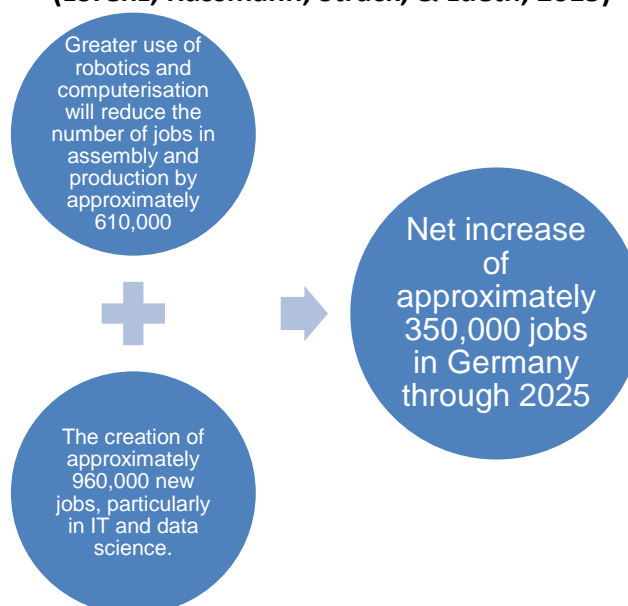
1.4   IMPACT ON THE WORKFORCE

The introduction of Industry 4.0 will have significant implications for employment and recruitment within industrial organisations and will have associated effects on educational systems and governmental policies.   While moves towards increased automation in manufacturing will threaten industrial positions, the introduction of new roles will be necessary to service the SMART factories of the future and the cyber-physical systems operating in them.   The transition to Industry 4.0 should therefore be considered as a re-allocation of labour with a key focus on the reskilling and training of the existing workforce to operate effectively within digital enterprises.

This concept was presented in a report by The Boston Consulting Group (BCG) titled "*Man and Machine in Industry 4.0: How Will Technology Transform the Industrial Workforce Through 2025?*"   The authors offered the following recommendations to business leaders and policy makers for how they can foster the adoption of Industry 4.0 and thereby enhance the productivity and growth of the industrial workforce.

 "Companies need to retrain their workforces, revamp their organisation models, and develop strategic approaches to recruiting and workforce planning. Education systems should seek to provide broader skill sets and close the impending gap in IT skills. Governments can explore ways to improve the central coordination of initiatives that promote job creation." (Lorenz, Russmann, Strack, & Lueth, 2015)

The same report forecasts a 350,000 net increase on the German industrial workforce in the lead up to 2025 (Fig. 3).

**Figure 3: Net effect on German Industrial Labour due to Industry 4.0
(Lorenz, Russmann, Strack, & Lueth, 2015)**

Greater use of robotics and computerisation will reduce the number of jobs in assembly and production by approximately 610,000

The creation of approximately 960,000 new jobs, particularly in IT and data science.

Net increase of approximately 350,000 jobs in Germany through 2025

From Fig 3 we see that the threat to employment is offset by the generation of greater numbers of higher value roles. Previous technology shifts have resulted in the re-shaping of the workforce towards higher value professions and Industry 4.0 is no different. In its 'From Brawns to Brains' report, Deloitte suggests that *"technology has potentially contributed to the loss of 800,000 jobs in the last 15 years, but helped to create nearly 3.5 million new highly skilled roles paying, on average, £10,000 a year more."* (Deloitte LLP, 2015). In addition, a 2015 study from London's Centre for Economic Research found that automation is helping to boost productivity more than cut jobs (Muro & Andes, 2015). Studies suggest that the general impact on the workforce is, at worst, equivocal and, at best, positive. The dullest, most repetitive (and often lowest paying jobs) will be outsourced to robots but more trained technicians will be required to operate SMART factories, maintain them and keep things running (Tarantola, 2017).

This will also mean that the practice of off-shoring the lowest paid roles to low pay countries is likely to change as manufacturers in developed countries look to in-shore their supply chains to take advantage of the high skill base of indigenous workforces to implement autonomous technological solutions and to support the demand for highly skilled equipment maintainers, operators and support staff.

Industry 4.0 has the potential to be a competitive differentiator, as companies that position themselves as technologically advanced, data-driven and highly innovative become more attractive to a new emerging workforce and studentship. A recent article from KPMG, *"Industry 4.0: It's all about the people",* highlights the challenges that HR Leaders in particular will face in addressing this massive shift in the workforce landscape.

"The challenge is significant. HR leaders will need to identify the new skills and capabilities that will realistically be required in the future. Those current employees willing and able to be upskilled and retrained will need to be identified. New talent will need to be attracted, retained and integrated into the business. New ways of working will need to be developed and formalised. And, all the while, the factory floor will need to keep operating and the business will need to keep growing." (Gates & Bremicker, 2017)

Skills needed for Industry 4.0

The World Economic Forum's 'Future of Jobs' Survey provides an indication of what leading global employers predict the change in core skills across industries and geographies to be by 2020. The Top 10 skills predicted in 2020 compared to those of 2015 are given below (World Economic Forum, 2016):

2020:	2015:
1. **Complex Problem Solving**	1. **Complex Problem Solving**
2. **Critical Thinking**	2. **Coordinating with Other**
3. **Creativity**	3. **People Management**
4. **People Management**	4. **Critical Thinking**
5. **Coordinating with Others**	5. **Negotiation**
6. **Emotional Intelligence**	6. **Quality Control**
7. **Judgement and Decision Making**	7. **Service Orientation**
8. **Service Orientation**	8. **Judgement and Decision Making**
9. **Negotiation**	9. **Active Listening**
10. **Cognitive Flexibility**	10. **Creativity**

By 2020, creativity will become one of the top three skills workers need. Computer automation and artificial intelligence is yet to be as creative as humans and it is envisaged that the introduction of new technologies, products and ways of working will require workers to become more creative to take advantage of these changes. Conversely, the increased use of machines, using masses of data to assist with decision making will relegate the importance of negotiation and flexibility skills which were high in the 2015 list. Active listening which is a core skill today, no longer makes the top 10 in 2020, but with emotional intelligence becoming a priority skill needed by all. Overall, over one-third of key skills considered important in 2015 will have changed by 2020 (Gray, 2016).

Procurement and Supply Chain Roles and Skills

The vision of Industry 4.0 involves a world in which everything speaks to each other forming a continuous network of information exchange. The role of Procurement and Supply Chain function, as the primary owner of the supplier interface, will be to take responsibility for the management of the 'value network' that connects an organisation to those external to it (Shute, 2017). To support Industry 4.0, Procurement and Supply Chain will have to develop new skill-sets, chief amongst which will be those related to the collection, analysis and repurposing of data to identify new business opportunities. The function will be expected to seize these opportunities to develop new value propositions that move it from being a cost to a profit centre (Batra, 2017).

While Procurement and Supply Chain operations will become ever more automated and therefore will require fewer people to manage, the smaller number of Procurement and Supply Chain Professionals left will need to have core attributes in emotional intelligence, creativity and influence that are currently lacking in digitalisation (KPMG, 2016) and will be able to act decisively on real time data analytics to deliver future value propositions.

The traditional role of Procurement and Supply Chain professions is therefore expected to evolve as suggested in Table 2 below (Batra, 2017):

Table 2: Difference between traditional Procurement and Supply Chain roles and those required under Industry 4.0

Traditional Procurement and Supply Chain	Industry 4.0 Procurement and Supply Chain
- Knowledgeable about Procurement and Supply Chain matters - Less technology knowledge - Transactional negotiation/T&C skills - One dimensional supplier relationships - Focus on short term benefits - Priorities driven by technical community	- Multi-faceted knowledge manager - Centre of Excellence on business/markets - Understands the evolution of technology - Acts as a consultant to the wider organisation - Holistic relationship management - Strong analytical management skills - Focus on complex deals - Ability to influence and lead change

1.5   Summary of Benefits and Challenges

Table 3 below outlines some of the key benefits and challenges associated with Industry 4.0 in general, for the Aerospace and Defence Sector and finally for Procurement and Supply Chain in particular.

Table 3: Benefits and Challenges of Industry 4.0

	Benefits	Challenges
General	• Access to new technology at affordable cost enhances organisational capabilty and productivity • Increased profitability through increased organisational productivity and cost efficiency • Manufacturing and Aftersales support/maintenance becomes *predictive* instead of *reactive* • Increasing efficiency through error reduction and process automisation and optimisation • Removal of non-value added activities • Potentially unprecedented access to new data sources to improve decision making and to identify new sources of value • Potential Industrial labour reductions	• Change required in business philosophy and investment strategies • The inertia of large organisations may lack the responsiveness and flexibility needed to implement Industry 4.0 effectively. • Shifts towards Industry 4.0 will require a substantial change in worker roles, not limited to manufacturing for which there will be a retraining or labour sourcing liability • New requirement for specialised labour to maintain new Cyber-Physical Systems • Lack of understanding (only 8% UK firms understand Industry 4.0) [Business Weekly] means that it is unclear what the actual end state is meant to be. • High levels of investment required in Cyber-Physical Systems • Some companies have not reached the 3rd Industrial Revolution so these companies still need to focus on efficiency and product quality before embracing Industry 4.0. • Data management costs, risks, volume and quality of Big Data will need to be stored, analysed and protected • Industry 4.0 is an idealised state – the perceived end state may be very different to what actually occurs due to the exponential advancement of technology. • Given the speed of technological advancement, there is a hightened risk of overcommittment to obsolescent technology. • The level of investment and resource required will create barriers for SMEs who will not have access to these on the same scale as larger organisations.

Aerospace & Defence	• Complex processes and procedures typical to the A&D Inudstry can be simplified through automation, and error rates reduced through Augmented reality. • Even if all Industry 4.0 objectives cannot be achieved for A&D, the limited application of specific Industry 4.0 technologies can still lead to some improvements in productivity and profitability	• There is significant business philosophy change and investment required particularly in A&D to overcome barriers to change • The A&D sector is generally resistant to change, and Industry 4.0 requires significant changes to human and commercial behaviour (i.e. data sharing and not exploiting advantages soley for an organisation's commercial gain) • Inter-company relationships in A&D are typically adversarial and may not support the level of collaboration required • A&D compliance requirements add complexity not present in other industries i.e.security and trade controls are a heightened issue in A&D, creating additional barriers compared to other industries, e.g. for the widespread adoption of Cloud based computing
Procurement & Supply Chain	• Transactional procurement can be made automous, liberating resource for strategic matters • Potential access to unprecedented levels of supply chain data enabling holistic supply chain visibility, improving risk and cost management • Procurement and Supply Chain as a function will increase its strategic influence on a business through the drive for securing Intellectual Property. • Big Data and sophisticated analytics are likely to enable dynamic value driven procurement and supply chain decisions, improve supply chain agility, increase the capacity to customise, and enhance value delivery to the end customer • The Procurement and Supply Chain function can re-invest cost savings in new I4.0 technologies for added value to the business	• Increased need for collaboration with companies, universities and research bodies will place additional challenges on Procurement and Supply Chain resources for intensive supplier relationship management • Challenges in A&D information sharing will hamper the ability for Procurement and Supply Chain to collaborate with partners

PART 2

Big Data

Augmented Reality

Systems Integration

Additive Manufacturing

INDUSTRY 4.0 TECHNOLOGIES

Cloud Computing

Autonomous Robots

Internet of Things

Simulation

Cyber Security

Original Diagram

2.1   BIG DATA

The introduction of Information Technology enabled the digitalisation of business procedures and the automation of some manual tasks; improving operational efficiency. From this process, IT systems started generating data about business operations, products and services that, once analysed, allowed organisations to optimise their businesses (CYIENT Data Analytics, 2018). With the advent of progressive developments such as the Internet, social media and the fledgling Internet of Things, data is being driven to new levels of complexity. Its abundance offers numerous opportunities for organisations to further enhance their operations and identify new business opportunities, (CYIENT Data Analytics, 2018) if suitable analytical methods can be found to make sense of it.

The huge growth in data was expected, and the term 'Big Data' was a term coined in the early 2000s to describe the massive volumes of data that were becoming available to businesses. Over time the number of characteristics have grown from the core '*3-Vs*' which are highlighted in green in figure 4 to up to as many as 42 in some sources (Tom Shafe, 2017).

Figure 4: Big Data Characteristics

VOLUME	VALUE	VERACITY
How much data we have – what used to be measured in Gigabytes (GB) is now measured in Zettabytes (ZB) (10^{12} GB) or even Yottabytes (YB) (10^{15} GB).	Embarking on a big data strategy is meaningless if you don't derive business value from that data. Potential value must be measured against cost and effort.	Distinguishing between information and disinformation, which requires processes to identify reliable data sources and keep the bad data from accumulating in your systems.
VISUALISATION	**VARIETY**	**VELOCITY**
Can the data be made sense of at a glance? Does it trigger a decision? Current formats and tools are limited and face technical challenges.	Variety describes one of the biggest challenges of big data. Organising unstructured, unformatted and rapidly changing data in a meaningful way is a huge task.	Velocity is the speed in which data is accessible. If it's not real-time it's no longer fast enough in today's environment.
VULNERABILITY	**VOLATILITY**	**VIRALITY**
Big data presents new security concerns that have the capability to evolve with the process itself. The ability to assure the safety of data has become critical.	How long is our data considered relevant or useful? Old archiving habits will not work with big data volumes. The costs and complexity of a storage and retrieval process are magnified.	The newest driver for big data analysis. Does the data convey a message? Can the message be easily transferred between media platforms?

While gathering and storing data for analysis was not a new concept, a distinction had to be made due to the sheer scale of the data that was now inundating businesses on a daily basis (SAS Institute Inc., 2017). Data flows were becoming too large and complex to process using traditional database management methods and conventional analytical software (Tonidandel, King, & Cortina, 2015) . Computing power per dollar has increased by a factor of ten roughly every four years over the last quarter of a century. While the rate has slowed in recent years towards an order of magnitude every 10-16 years (AI Impacts, 2015), sufficient computing power to undertake large scale data analysis on diverse data sets has now become commercially viable, easier to use and, therefore, widely accessible for companies of all sizes. As a result, the opportunity to realising tangible benefits from Big Data has driven increased business interest.

Procurement and Supply Chain Impact

Big Data is about to make a big impact on procurement and supply chain operations by creating new types of applications and information services, as well as by improving existing applications (Busch, 2012). For example, interactive dashboards on suppliers or commodities could be updated in real-time with internal and external information. The key benefits it enables are (Busch, 2012):

- **The analysis of larger and more complex datasets –** not only traditional spend and invoice data, but also other more complex procurement and supply chain information from various internal and external sources such as contract terms/information, part and bill of material data, supplier performance and supply chain information.

- **The combination of disparate datasets that blur the line between procurement and operations –** Big Data analytics allows datasets from different sources to be merged, enabling the better management of complex engagements and relationships across internal functions and with the external supply chain.

- **Faster fact finding and reporting –** Queries can be run faster and will involve more scenario modelling to optimise sourcing decisions based on internal constraints and

market forecasts. Spend will be able to be looked at in many new ways to more quickly identify opportunities and leverage data insights.

- **Solving complex sourcing challenges –** The ability to optimise common sourcing events will be one of the first areas where Big Data is expected to have a big impact on procurement and supply chain organisations. It will allow these organisations to make better sourcing decisions based on total cost, and optimise for lower cost structures prior to sourcing events themselves. For example, by automatically suggesting specification changes.

- **Enhanced predictive capabilities for strategy adjustment –** Big Data analytics will enable changes in market and supply chain conditions to be continuously monitored, and their effects forecast more accurately, enabling strategies and management methods to adjust more proactively to underlying conditions and fluid scenarios.

Aerospace and Defence Sector Applications

The potential application of Big Data analysis is extremely diverse in the Aerospace and Defence sector, but data security presents a challenge. Whilst technical advances over recent years have created the platforms needed to collect and process vast volumes of structured and unstructured data in a meaningful way, the inherent risk associated with securing this data has hampered widespread adoption across the sector.

Overcoming the obstacle of certifying and managing data assurance and security is certainly the first step towards widespread adoption and, as a result, the focus on Cyber Security has risen in recent years. Once adopted, a number of new possibilities become available in the sector. Utilising real time data telemetry streams from sensors embedded in platforms such as autonomous vehicles, drones, satellites, and connected reconnaissance tools could yield constant, live streams of data which can be processed to gain insights into equipment performance and reliability as well as enhance maintenance, repair and operational processes.

2.2   SYSTEMS INTEGRATION

Systems integration is an engineering term which describes the conjoining of different subsystems or components into one large system; ensuring that each integrated subsystem functions as required. More often than not, additional value can be realised through new functionalities provided by connecting the various different subsystems (Techopedia, 2018). Systems integration is among the key enabling technologies for Industry 4.0 and especially in developing the Internet of Things (Gurney, 2016).

The principle motive behind Industry 4.0 is utilising the interconnectivity of physical and cyber systems to gain new data streams, which can be analysed and converted into insights to yield new business opportunities and ways to enhance operations. As such, the ability to integrate systems is critical to the effective implementation of Industry 4.0. The challenge is that Industry 4.0 technologies use a wide array of disparate systems and applications, all of which will require seamless integration to create the Internet of Things and the SMART manufacturing factories of the future. Other Industry 4.0 technologies offer the relevant capabilities to do so, i.e. cloud computing allows disparate platforms to communicate via a series of standardised protocols however the task of ensuring that separate systems can communicate with each other should not be underestimated, especially in the absence of formal Industry 4.0 standards regulating what protocols should be used.

In a manufacturing engineering context, systems integration will involve establishing the cyber-physical systems that enable data to be gathered directly from the plant floor to generate actionable information that is of real-time value (Gurney, 2016). It also applies to the bringing together of systems which increase automation and organisational capability. This can apply within an organisation, such as the integration of Artificial Intelligence into cross organisation IT (Enterprise Resource Planning ('ERP')) systems, or between organisations. The Procurement and Supply Chain function will be impacted by both applications. For example within an organisation; Procurement and Supply Chain Professionals will benefit from the integration of systems designed to automate limited value adding transactional or clerical activities with existing e-Procurement and Supply Chain Management systems. This particular example will reduce error rates and liberate

time which can then be used to focus on more strategically important, higher value-adding matters.

Systems integration will also enable Buyer and Supplier systems to become connected across organisational boundaries. The natural aspiration of such integration will be the sharing and communication of information across entire value chains. When coupled with the sophisticated data analytics developments also central to Industry 4.0, the instant and uninterrupted flow of data across members of a supply chain network will enable Procurement and Supply Chain Professionals to more proactively manage supplier performance and adjust buying strategies to changing factors in the supply chain. This will be one of the key differentiators between the procurement of old and procurement under Industry 4.0 (Nicoletti, 2017). It will also be one that the function will be expected to lead. Cross supply chain systems integration will only be possible if the principles and mechanisms for collaboration can be secured with external organisations with the onus on the Procurement and Supply Chain function to establish the necessary relationships and agreements to facilitate such arrangements.

2.3   CLOUD COMPUTING

Cloud computing is the on-demand delivery of computer power, database storage, software applications, and other IT resources through an internet based cloud services platform (Amazon Web Services, 2018).

In the same manner to when a hire car is leased, giving the hirer full use of the vehicle without any ownership, cloud computing allows companies to lease computing capabilities without any need to own and/or maintain any of the relevant IT infrastructure. It is most commonly associated with the provision of external storage capacity but a wide range of management applications are also available from cloud providers. Within a business context, many business management applications like customer relationship management and enterprise resource planning are based on a cloud service provider and the high processing power along with the sophistication of tools available make cloud services the preferential choice for mining Big Data (newgenapps, 2017). In fact, without cloud computing, it would be prohibtively difficult to collect and analyse data in real time, especially for small companies (newgenapps, 2017).

Procurement and Supply Chain Impact:

Companies are increasingly looking to apply cloud computing in their supply chains to take advantage of the following impacts (Markim, 2015):

- **Reduced Costs** – The greatest benefit of cloud technology to supply chain management is the reduction of operational costs. Cloud computing can reduce the resource needed to complete specific tasks and lower costs associated with security, IT infrastructure and data analysis.
- **Advancements in Analytical Capabilities** – Cloud technology, with the Internet of Things (see next Section), enables the rapid collection and analysis of high volumes of data. This allows businesses to reduce the headcount in data analytical positions while still generating the data driven insights that facilitate good decision making, just at an exponentially quicker rate.

- **Integration of Multiple Supply Chain Management Platforms** – More businesses than ever use 3rd party supply chain management solutions and multiple platforms now exist, many of which are not compatible with each other. Cloud computing allows these multiple platforms to communicate and work together through a series of standardised protocols, breaking down digitial barriers and increasing the speed of communication and order fulfillment.

- **Removal of Geographical and Political Boundaries** – Many cloud hosts rely on common practices that have been adopted worldwide and so the same information can be altered from anywhere and with an objectivity that removes political debates from business pratices.

- **Enhanced Security Measures** – Cloud hosts have to abide by strict government and regulatory standards so typically employ state of the art security measures. Interconnectedness also allows for widespread security monitoring.

- **Increased IT Capabilties** – Using cloud providers typically allow companies to reduce the size of their in-house IT departments. It can also increase their capability by providing access to multibillion-pound technology infrastructures and enhanced support options due to the cost being amortised across the network by other users (CIPS, Cloud Computing in the Supply Chain, 2014).

- **Increased Scalability Abilities** – Should an organisation need to grow its IT capabilites (or reduce them), it is relatively easy to extend (or reduce) the cloud service with a host. This gives organisations additional flexibility in periods of growth (or decline).

There remain a number of disadvantages that must be considered (CIPS, Cloud Computing in the Supply Chain, 2014):

- **Trust issues -** organisational decisions to switch to cloud computing are heavily influenced by persisting trust issues arising from questions such as – how much information is shared and how early? Could information leak to others on the same cloud host, or further afield (especially if competitors are also using cloud based systems)?

- **Remaining compatibility issues –** Most big software companies promote the use of their own cloud offerings meaning that the choice of providers to use can be limited and heavily influenced by which software systems are currently in use. This leads to a lack of buying power in the market and a risk of the cloud provider taking advantage of a dominant negotiating position.

Without the means for organisations to store and analyse the huge volumes of data that will be generated as cyber-physical systems, value chains, and partner organisations become ever more connected, the headline benefits of Industry 4.0 will not be achieved. As such, cloud computing is a critical enabler for Industry 4.0. While it remains the only practical way of meeting the business demands for real time, analysed information, issues around information sharing and cyber security remain some of the greatest challenges to adoption. This is especially true within the Aerospace and Defence sector, which has been slow to embrace cloud computing compared to other sectors. This is understandable given the particularly sensitive nature of some information and assets. However as cloud computing becomes the business norm, it is expected that the sector will have to adopt it as non-cloud options are phased out and continuing to maintain non-cloud systems becomes prohibitively expensive.

2.4   THE INTERNET OF THINGS

A key feature of Industry 4.0 is the increasing interconnectivity between objects and people typically referred to as "The Internet of Things" ('IoT'). This concept has been defined as "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies" (ITU-T, 2013). Through system integration, real world objects and devices can be connected, where telemetry can then be gathered and stored in the cloud, enabling instant real time data exchange and remote control and reporting on any connected devices; local or mobile (Gurney, 2016). This concept is essential to creating the SMART facilities of the future such as "Smart Homes" and "Smart Factories".

The IoT is already impacting on Procurement and Supply Chain operations with forward thinking companies such as Amazon using it to create more agile supply options for their customers by supplying based on real time consumer demand signals to improve customer demand satisfaction. For example, Amazon's Dash button introduces a physical device into the home which allows for re-order of regularly used products like toiletries. When pressed, a demand signal to procure more stock is sent via the internet to the owner's Amazon account. This then uses pre-agreed cost and delivery parameters to place an order with Amazon. The stock is picked and sent out to the logistics provider to be delivered and upon delivery, payment is deducted from the owner's bank account. The order information is then stored on an Amazon database and may influence selective direct advertisement by Amazon to the customer on similar products that they may be interested in (Baguley & McDonald, 2016). This principle is easily applied to consumer products or low value off the shelf goods, but applying it to Procurement of a complex system or engineering product is still a developing concept in the Aerospace and Defence Industry.

A key application for the Procurement of complex systems is in the interconnectivity of physical components and health monitoring systems which can be used to influence re-stocking and preventative maintenance schedules. While these assets are generally expensive to procure, over their operational life span, maintenance and repair costs can

sometimes dwarf the initial expenditure required. If real time diagnostic information is available about the health of an asset, more focused and cost effective preventative maintenance can be undertaken to reduce the risk of failure and to provide an accurate forecast of when and what Procurement activities need to be undertaken to support the ongoing operation of the asset.

Without sensing and intelligent analytics, repairs can only really be determined when products actually fail. By introducing sensors and connecting the telemetry to diagnostic software, asset repairs can be predicted prior to failure. This will significantly improve asset availability, safety and maintenance costs by enabling parts to be replaced before their failure threshold is reached.

A real example of this in practice is the Airplane Health Management ('AHM') system which can be connected to a Boeing 777. The AHM "automatically collects airplane data and fault information, then prioritizes and organizes the data to assist operators in formulating a plan for repairs" (Maggiore, 2007).

Applications like Amazon's Dash button and Boeing's AHM system will significantly influence future Procurement and Supply Chain activities. Interconnectivity effectively enhances existing ERP systems through the incorporation of new data nodes into a business information infrastructure. With increased connectivity between physical assets and an organisation's business system, orders can be placed autonomously with the supply chain within set price and delivery parameters depending on the outputs of integrated system diagnostics. This is likely to reduce the need for transactional procurement roles and enabling Procurement and Supply Chain professional to focus on more strategic, greater value adding activities.

IoT will bring about a new wealth of data and analytics. Organisations will have to secure the required Intellectual Property rights to access and use this data on a much wider scale than today and it is entirely conceivable that data may become commoditized. In this vision of the future, as the organisation's primary interface with the external value chain, the Procurement and Supply Chain function will play a pivotal role in forming and

maintaining the collaborative relationships with supply chain partners needed to buy (and possibly sell) the data that the organisation needs to establish value chain interconnectivity.

2.5   CYBER SECURITY

In 2009, the Stuxnet malware virus infiltrated the systems of a nuclear enrichment plant, causing centrifuges to spin out of control. This virus was introduced into stand-alone networks via flash drives and autonomously spread across the various production networks (Waslo, Lewis, Hajj, & Carton, 2017).   This example highlights how the increasing connectivity of smart machinery can mean that cyber-attacks have the potential to cause far more disruptive effects than ever before.   Enhancing digital capabilities throughout manufacturing and supply chain may bring new cyber risks that organisations must prepare for (Waslo, Lewis, Hajj, & Carton, 2017).

Industry 4.0 technologies are likely to cause an evolution in the traditional concept of a linear supply chain and move towards intelligent, connected platforms, devices and systems within supply ecosystems that are capable of capturing data from points across the entire value chain to inform the actions taken at others.   This also gives risk to new cyber vulnerabilities that must be addressed by manufacturers (Waslo, Lewis, Hajj, & Carton, 2017):

- **Unauthorised access -** A fully agile and responsive supply ecosystem is likely to require open access to data. This increases the risk of unauthorised access and increases the need for robust cyber defences to safeguard proprietary and/or sensitive information

- **Greater target profile -** The increased networking and usage of commercial off-the-shelf products in industrial control systems introduces a greater variety of targets that could be attacked

- **Impact on cyber controlled physical systems -** Where cyber-attacks on IT systems have typically targeted information, cyber-attacks on SMART factories are more likely to target physical processes, having a greater impact on production, customers, manufacturers and products themselves.

- **Enduring aftermarket risks -** If manufacturers produce products that themselves are connected technologies, then cyber risks can extend beyond sale of the product

and manufacturers will be reliant on customers ensuring that effective cyber security controls are maintained to avoid introducing further vulnerabilities to their own cyber security safeguards.

Organisations embracing the new technological revolution will have to accept that cyber security risks will grow significantly with the level of connectivity and integration. As a cyber attacker only needs to target the weakest point within a connected supply network to gain access to an organisation's systems, the degree to which an organisation is vulnerable to such risks may grow exponentially as additional connections are made with organisations and devices across its value chain (Waslo, Lewis, Hajj, & Carton, 2017). Therefore it is critical that manufacturers seeking to move to Industry 4.0 operations understand the collective responsibility that all connected organisations share, the risk posed by meeting only the minimum standards provided by regulatory and industry standards and the holistic need to reassess their business continuity, disaster recovery and response plans in light of an increasingly threatening cyber environment.

2.6   SIMULATION

Simulation is the representation of the functioning of a system or process.   Through simulation, virtual imitations of an object or phenomena may be varied to produce complex scenarios which enable analysis and understanding of how individual elements interact and affect a simulated environment, process or system (Simulation Australasia, 2017).

Modelling and Simulation technologies are already widely used for the research, development and design stages of new products/services.   It enables rapid design development; lower cost prototyping compared to physical alternatives and offers increased support options to train operators and engineers in the operation and maintenance of products (SIMWARE, 2017).   The role of simulation is increased under Industry 4.0 as product research and development shall be undertaken in simulated laboratories utilising digital production and fabrication models enabling those Industry 4.0 adopters to develop smart products faster and more competitively than non-adopters (SIMWARE, 2017).

The applications of Industry 4.0 are not limited to simulation based engineering of products. With the connectivity of cyber-physical manufacturing systems under Industry 4.0, data can be used to instantly see how a factory is running and how it can be optimised further (Visual Components, 2015).   For instance, manufacturing simulation software can enable (Visual Components, 2016):

- **The virtual testing of production line changes** – testing the performance of a production line in a risk free virtual world to identify issues and improvements prior to the real world changes being made;

- **Pre-emptive performance troubleshooting –** simulation can help identify and visualise issues that are preventing optimal factory performance;

- **Production line optimisation –** changes needed for performance improvements can be identified by testing and simulating process changes;

- **What-if modelling –** various scenarios which may affect production can be modelled so that appropriate responses can be found;

- **Increased predictability –** simulation can enhance capabilities at forecasting production line operations to help plan more accurate delivery schedules; and

- **Quantitative management information –** supporting data about the production line can be used to provide increased insight into areas like Return on Investment for proposed changes and to support cost-benefit analyses; both of which aid decision making.

Procurement and Supply Chain impact:

Computer-based modelling and simulation of real and test supply systems have been widely available for many years. These allow an organisation to analyse and experiment with its supply chain processes in a risk-free virtual setting. Through the use of supply chain simulation, businesses can understand the factors that affect their system through a factual statistical approach, including evaluation of unknown problems, decision analysis, risk management and future project planning (FlexSim, 2018). This reduces the time and cost associated with physical testing and allows the safe exploration of risks within complex supply chains.

The advances in simulation capabilities mentioned above are not limited to a manufacturing context and developments in simulation for Industry 4.0 will also benefit Procurement and Supply Chain professionals by enhancing the sophistication of simulation tools at their disposal. This will lead to more proactive and dynamic supply chain management, greater control of risk, enhanced surety of supply and ultimately increased supply chain competitiveness and bottom line contribution.

2.7   ROBOTS

An Industrial Robot is any robotic system used for manufacturing which is an automatically controlled, reprogrammable, multipurpose manipulator in three or more axes (Science Daily, 2018). Robots have been employed in manufacturing operations since 1961 when the first industrial robot, *Unimate 1900*, became the first mass produced robotic arm for use on a production line. According to the International Federation of Robotics, by 2015 the count of industrial robots had risen to 1.63m worldwide with the automotive sector accounting for the greatest market share (35%) (The Economist, 2017) and with 59% of all manufacturers currently use some kind of robotics technology (McCutcheon & Pethick, 2017).

Robots are used because (Acieta LLC, 2018):

- **They are highly cost-effective at generating efficiencies –** this is true throughout the product value chain and increasingly amongst manufacturer's of all sizes (high volume production remains a mainstay however more value adding roles for robots are being found in Small and Medium Enterprises)
- **Reduces the risk to humans –** any repetitive production task is a candidate for robotic manufacturing, especially if it is dangerous to humans. As robots become more adaptive and their versatility improves, their potential applications expand.
- **Robotic equipment is becoming more flexible and customisable** to perform more complex tasks
- **They can be programmed to operate 24/7** under continuous production conditions
- **They are becoming pre-requisite for competitiveness –** with increased use, manufacturers are finding that they need to embrace robotics to stay competitive.

Robots have traditionally been limited to single specific functions such as welding, painting, assembly, applying glue or heavy lifting but as they are becoming smarter, faster and cheaper and gaining additional 'human' capabilities such as sensing, dexterity, memory and trainability so can perform ever more complex applications such as picking & packaging and product inspection & testing (McCutcheon & Pethick, 2017). A new generation of robots are emerging that are smarter, more mobile, collaborative and adaptable to work alongside humans without endangerment. They can now support the assembly of products as large as

aircraft engines and as small and delicate as smartphones and can be easily repurposed for increased product customisability (Hagerty, 2015).

Procurement and Supply Chain and Robots, Automation and Artificial Intelligence

Beyond manufacturing, the concept of a robot is not limited to a machine that only functions as a manipulator of physical objects but instead refers to the more general proposition of a machine capable of carrying out a complex series of actions automatically. Autonomous robots have the potential of enhancing everyday business activities, especially when coupled with developments in Artificial Intelligence ('AI') by increasing (Jenks, 2017):

- **Automation –** removes the need for human intervention and allows robots to perform key process steps (physical or otherwise)

- **Augmentation –** the assistance that is provided to humans to complete their daily tasks.

Procurement and Supply Chain have already seen the arrival of certain autonomous robots in the form of 'Robotic Process Automation' ('RPA') (Shute, 2017). RPA is a "software application that runs on an end user's computer, laptop or other device, emulating tasks executed by human operators…[where] its purpose is to integrate or automate the execution of repetitive, rule-based tasks or activities" (Procurious HQ, 2016). Such tools are designed to take away the need for humans to perform simple, repetitive, clerical duties, freeing up time for Procurement and Supply Chain Professionals to dedicate to more value adding activities (Shute, 2017).

Within a Procurement environment, RPA can (Vollmer, 2017):

- **Ensure appropriate inventory levels are maintained consistently and with minimal human intervention –** The issuing of material/service requisitions and purchase orders can be automated through the robotic monitoring of inventory and use of automatic resupply triggers when stock levels fall below a certain, pre-set threshold.

- **Accelerate data-driven insights and actions –** Computing software and machine learning can allow data to be extracted from various internal and external sources and converted into a format that can be utilised effectively by Procurement and

Supply Chain Professionals. Natural Language Processing also means that incoming communications can be read by RPA software, the meaning detected and a response issued based on the available information to complete tasks without human intervention within parameters defined by the organisation.

- **Mitigate risk dynamically and with greater accuracy –** RPA can continuously monitor risk exposure and determine the causes of such movement objectively, sift lengthy and complex risk reports, legislation and regulations, identify compliance gaps and provide insight on how to close them; enabling Procurement and Supply Chain Professionals to more proactively manage their risks.

In additional to enhancements in the areas covered above, one current vision of the near future for the application of AI within Supply Chain Management activities also includes (Jenks, 2017):

- **Chatbots for Operational Procurement –** used to assist with daily tasks to:
  - o Speak to suppliers during trivial conversations;
  - o Set and send actions to suppliers;
  - o Place purchasing orders;
  - o Receiving, filing and documenting invoices and payments.

- **Machine Learning for Supply Chain Planning –** to assist with forecasting within inventory, demand and supply, by generating best possible scenarios based on intelligent algorithms and the analysis of big data sets to optimise delivery of goods/services while balancing market factors.

- **Machine Learning for Warehouse Management –** Machine Learning allows a continuous loop of forecasting as the AI can constantly look to see what algorithm combinations and data streams have the most predictive power, enabling it to produce a constantly self-improving output.

- **Autonomous Vehicles for Logistics and Supply –** Driverless delivery mechanisms can allow for faster and more accurate shipping which reduce lead times and transport expenses and enable more environmentally friendly operations.

- **Machine Learning and Predictive Analytics for Supplier Selection and Supplier Relationship Management –** Machine Learning and Predictive Analytics can be used to identify the best possible scenario in any supplier interaction for supplier selection and risk management and present it whatever format the Procurement and Supply Chain Professional desires to speed up report collation and dissemination.

As the cognitive power of AI increases and machines become ever more capable of performing complex tasks and trusted to make key organisational decisions, the ability of RPA to streamline Procurement and Supply Chain related tasks through automation and augmentation will only increase. The inevitable consequence of which will be threats to Procurement and Supply Chain jobs, first in the operational environments dominated by low skill, repetitive, clerical tasks but increasingly applicable to roles involving more complex supply management activities. At present however, the adoption rate is "…moving at a snail's pace" (Vollmer, 2017). Uptake of RPA within the function remains immature with "77%" of companies … not [having] yet rolled out any RPA solutions" (Hackett Group, 2016) and only 7% of manufacturers currently using AI to automate production activities (Ramaswamy, 2017). This uptake will speed up though as AI technology develops further and becomes more widespread and commercially accessible.

2.8   ADDITIVE MANUFACTURING

What is Additive Manufacturing?

Through the use of a computer, 3D Computer Aided Design ('CAD') software, specific Additive Manufacturing ('AM') machine equipment and a suitable layering material, layer upon layer of materials such as plastic, metal or even concrete, can be built up to form 3D objects. AM encompasses the processes of 3D printing, rapid prototyping, direct digital manufacturing, layered manufacturing and additive fabrication (AMazing, 2018).

Despite being around since the 1980s, the technology is only just becoming commercially viable compared to conventional manufacturing processes (Defence iQ, 2016). While early forms of the technology focused on the creation of pre-production visualisation models; it is now being used to create end-use products in various industries (AMazing, 2018) and enabling organisations to push engineering boundaries and make more complex objects and products than ever before (Defence iQ, 2016).

Additive Manufacturing in Aerospace and Defence

The Aerospace and Defence sector leads the market in AM (the market leaders in the sector are given in Figure 6). This is unsurprising as many contracts in the sector require bespoke designs for components that are needed in low quantities. It can be expensive to acquire all the equipment needed to meet each contract requirement but AM removes the need for specialist machines for small batch production runs if they can all be produced using one 3D printer with the right CAD software (Defence iQ, 2016).

The main benefit of AM in the Aerospace and Defence sector is the lightweight properties of the finished items. Where conventional manufacturing combines component parts into assemblies, AM can build free form designs of complex, interconnecting parts with lattice structures and cavities to reduce weight without sacrificing structural integrity. Being lighter but as strong as traditional products has clear widespread advantages in the sector.

**Figure 7: A&D market leaders in additive manufacturing (Defence iQ, 2016)**
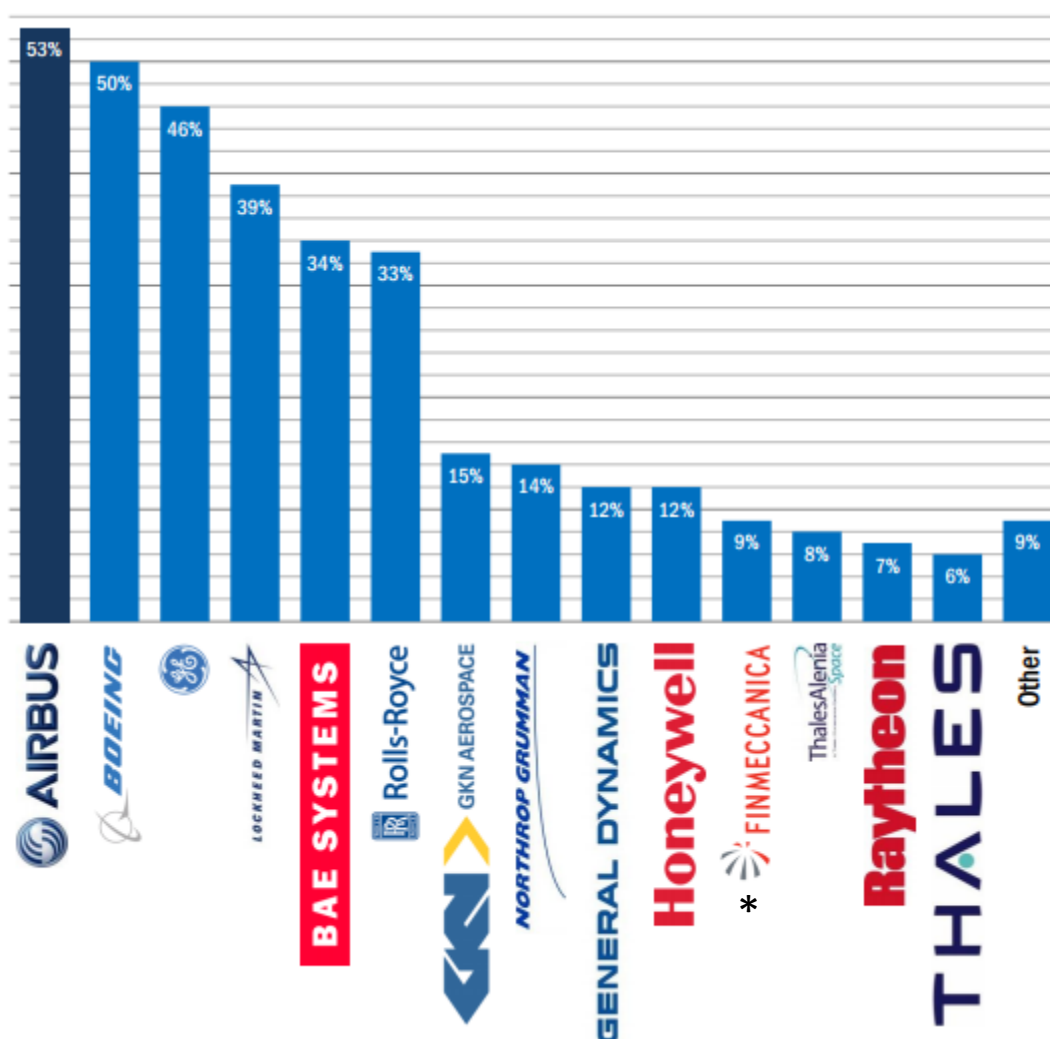
* Now Leonardo

Other advantages include:

- **Overcoming current engineering limitations –** AM allows Engineers to create complex geometries out of materials that conventional manufacturing cannot.

- **Deploying printing capability in-theatre for quicker repairs and upgrades –** Rather than relying on supply chains which may delay necessary repairs and/or upgrades, 3D printing enables rapid creation of bespoke parts.

- **Cost effective creation of bespoke parts –** At present, conventional manufacturing offers cost benefits where production volumes are high. AM is more attractive at low volumes (Fig 8) and offers a more efficient manufacturing process through the elimination of waste.

**Figure 8: Break-even analysis of 3D Printing vs Conventional Manufacture
(Deloitte, 2015)**
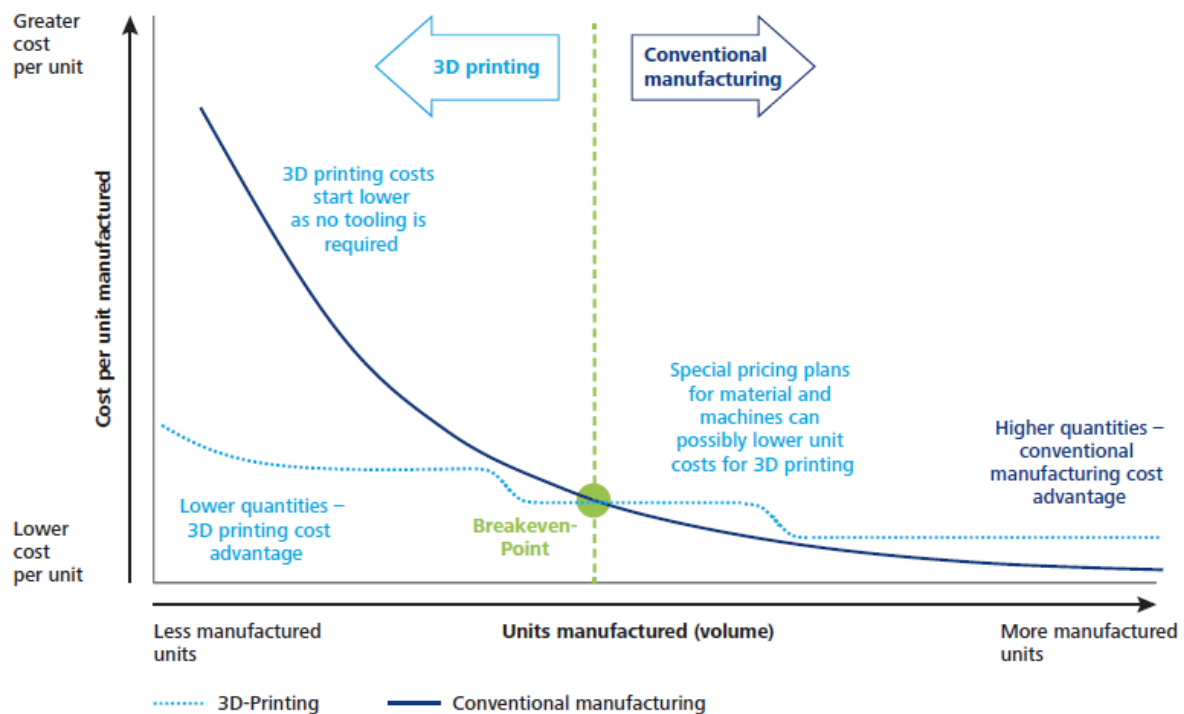
In comparison, there are also some disadvantages of AM that mean conventional manufacturing is preferable in certain situations (Deloitte, 2015):

- **The (currently) higher cost of mass production compared to conventional manufacturing –** as shown in Figure 8

- **The limited range of printable materials –** only certain polymers, metals and ceramics can currently be used

- **Size limitations –** 3D Printers impose a size limit on the size of parts that can be made

Additional challenges exist: (Defence iQ, 2016):

- **Certification of finished products**

- **Quality & standardisation of material inputs**

- **Achieving the necessary quality of printed components**

- **IP, legal and regulatory issues**

Examples of AM in Aerospace and Defence:

Boeing's Research and Technology team in St Louis has successfully used AM to manufacture molar fairings for the 737 MAX, model electronic boxes for 787 and test articles for use in wind tunnels. Boeing also broke a world record for the largest solid 3-D printed item – a wing trim and drill tool for the 777X (Fig. 9).

Figure 9: 3D Printed Wing trim for Boeing 777x (17.5 ft long, 5.5 ft wide and 1.5 ft tall) (Alec, 2016)

GE Additive has also established a 'network' of additive facilities in Asia, the US, Europe and South America. Some of their AM successes include Combustor swirlers for Oil and Gas applications, fuel nozzle tips for aircraft and even a Turboprop engine.

It is also worth noting that new Supply Chains will have to be considered prior to the implementation of AM. For instance, with material inputs being critical to AM, additional procurement focus will turn to the acquisition of raw materials, particularly metal and plastic commodities. Also, the effect on the sustainability of conventional manufacturers that are typically relied upon not just to manufacture and supply new products, but also to *design* them will have to be evaluated carefully. It is clear that AM creates complications around design ownership and Intellectual Property and care must be taken to ensure that a rush to adopt AM does not come at the cost of undermining the sustainability of existing markets to support future design development.

2.9   AUGMENTED REALITY

What is Augmented Reality?

Augmented Reality ('AR') is the integration of digital technology with a user's environment in real time using technology designed to overlay computer-generated information onto a view of the real world. It allows live data to be superimposed onto products, structures and assets improving data cognition by the user (Augment, 2015).

The range of potential applications for AR is wide and involves all kinds of operations from core manufacturing to support processes such as maintenance and training. For example, it can be used as a tool to improve design visualisation and it is also highly useful as a means of providing more visual training to field operatives where it can be effective for both experienced and new technicians at the start of their learning curve.

Another key application is to show operatives information about component parts of a system (or the system as a whole) (Fig. 10). Live telemetry can be overlaid via the AR technology to enable the rapid identification of defective components and show the correct procedure for replacing them.

Figure 10: Augmented Reality Tablet Display (MACHINES4U, 2017)

AR can challenge common inefficiencies and risks (HyperIndustry, 2017):

- **Human error** - Operatives can become overloaded by excessive procedures that have to be remembered or referred – AR can display the correct procedure to apply at the correct time and demonstrate exactly what the operator must do to complete the task;

- **Inefficiencies -** AR has been shown to reduce the execution times for assembly and maintenance operations and reduces some of the recurring sources of inefficiencies

(i.e. the use of inappropriate tools, inadequate training, low access to subject matter expertise and performance analytics);

- **Cost -** Longer operations, higher defect rates and component damage due to the execution of incorrect procedures increase product and labour related costs. By reducing human error and Inefficiencies, operating costs can be reduced.

Trends indicate that AR increases both people and process performance, thereby decreasing costs. First time fix rates have been demonstrated to be increased by 90% using AR technology with operator performance shown to improve by up to 50% (HyperIndustry, 2017). A 2015 Boeing internal study on the use of AR suggested that through the use of animated AR instructions trainees speed increased by 30% and accuracy by 90% in contrast to more traditional learning methods (Flex, 2018).

The Augmented Reality Market

The global AR market is expected to reach $117.40bn by 2022 from $4.4bn in 2016, with a CAGR of 75.72% (RnR Market Research, 2016).

Figure 11: Leaders and Notable Players in the AR

The market is dominated by consumer focussed organisations (market leaders and notable players given in Fig. 11). Industrial applications only accounted for 25% of the AR market in 2015. However AR technology is rapidly maturing and has reached sufficient maturity to be used within production environments for quality inspections, training and work instruction. Due to the demand for AR technologies for industrial applications significant growth is expected within the industrial sector (RnR Market Research, 2016).

Benefits and challenges of using Augmented Reality in the Aerospace and Defence Industry

In a sector where there is inherent engineering complexity, high asset costs, low margins of error and the need for high degrees of compliance with set procedures, standards and regulations, AR has a clear benefit as a pedagogical tool to assist industrial workforces in undertaking challenging operations, either directly on the frontline or in the classroom. It is also an industry were particular constraints limit some of the key enabling technologies needed for the benefits of AR to be fully realised. For instance, Wi-fi internet technology is required for the effective overlay of real time maintenance information on AR handsets however Wi-Fi is not available on or near some Aerospace and Defence platforms (e.g. submarines) due to security concerns. This severely limits ARs effectiveness for frontline operations. Effort is, however, being directed at developing solutions that will still enable AR to add benefit to the industry.

The Impact of Augmented Reality on Procurement and Supply Chain

AR technology is likely to have a number of key impacts on the Procurement and Supply Chain function:

- **The availability and visualisation of Procurement and Supply Chain information -** Just as an operative uses AR technology to visualise operational and performance information about a part, the same technology can be used to display information important to Procurement and Supply Chain Professionals such as spend data, analytics results or supply chains maps. The presentation of such information in an interactive format will increase the speed of cognition, increasing productivity in the function, improving communication with non-functional stakeholders and enhancing the speed at which data can be analysed and acted on, especially as data volumes grow.
- **Source of competitive advantage for Suppliers -** Early adopters of AR technology are likely to be the first to benefit from reduced production inefficiencies and an increased productivity in their workforce; both of which have the potential to cut operating costs and strengthen an organisation's competitive advantage.

- **Procurement and Supply Chain as a technology champion -** Manufacturing and production companies are typically looking to specialist AR technology companies to help establish their AR capability. Collaborative relationships will be required to maximise the value offered by AR technology and Procurement and Supply Chain has an opportunity to take a lead role in establishing and shaping the relationships with specialist third party companies investing in AR technology.

- **Information becomes as important as the product -** As the reliance on real time product information becomes ever more important to the effectiveness of AR capabilities, there will greater emphasis on the Procurement and Supply Chain function partnering with suppliers to secure the real time data updates and Intellectual Property Rights to support products and services through life.

Central to the concept of Industry 4.0 is the increasing interconnectivity of physical objects and machines with cyber management systems. For the implementation of Industry 4.0 to be effective, some form of user interface is required that gives humans the means of understanding and controlling the cyber-physical systems. AR technology is currently one of the key candidates to act as this interface, offering an easily accessible medium through which the ever increasing volume of Big Data can be understood and acted upon.

As a cognitive interface for cyber-physical systems, AR technology has applications throughout manufacturing organisations, from providing procedural assistance to frontline operators to enhance first time fix rates to helping functions make sense of the volumes of Big Data expected under Industry 4.0. While the Aerospace and Defence sector may lag behind consumer focussed sectors due to constraints within the sector, the benefits it could offer to a sector with such high degrees of inherent complexity mean that Aerospace and Defence is likely to find ways of adopting leading commercial off the shelf AR technology into their operations in the near future.

AN ADPG-NEXT GENERATION PERSPECTIVE

ON THE IMPACT OF INDUSTRY 4.0 ON PROCUREMENT AND SUPPLY CHAIN

The central premise of Industry 4.0 is that interconnectivity generates a new abundance of data that sophisticated analytical tools and interfacing technology can take advantage of to yield innovative insights into operating efficiencies and business models that can act as competitive differentiators. The interconnectivity critical to achieving these benefits are brought about by the integration of a number of enabling digital technologies. The Aerospace and Defence sector is taking strides to adopt a number of these such as Additive Manufacture ('AM') and Augmented Reality ('AR'). The benefits offered by these particular technologies lend themselves to a sector generally characterised by challenging manufacturing, maintenance and support operations, high procedural complexity, strict regulation and the importance of relatively small volume, high value bespoke items. While Cyber security is considered the greatest barrier to adoption across sectors, the barrier is especially high for Aerospace and Defence where heightened security constraints currently present an acute challenge to creating the 'open' cyber-physical networks across value chains needed to achieve the Industry 4.0 vision. While this challenge persists, despite the adoption of isolated technologies like AM and AR, Aerospace and Defence is likely to be limited in the benefits it can gain from the Fourth Industrial Revolution.

The Procurement and Supply Chain function has a duty to lead organisational efforts towards industrial digitialisation. Solutions to Aerospace and Defences' challenges of interconnectivity are likely to first become available from beyond the organisation, in wider supply markets. Procurement and Supply Chain professions must take a proactive role in finding these and then acting as internal consultants to challenge the current organisational practices and exert influence to advocate the new market offerings. Creativity is identified as one of the Top 3 skills in 2020 and Procurement and Supply Chain professionals will need to get creative in how they find solutions and how they interact with internal functions to see digital solutions implemented.

Interconnectivity will also require widespread collaboration between supply chain partners and the level of collaboration required will require a paradigm shift in attitudes towards

supply chain relationships. The Procurement and Supply Chain function is best placed to lead these efforts. In Aerospace and Defence, it is typical to consider most current supply chain relationships as adversarial and the industry has historically been slow to move away from draconian contracting methods. Compared to other industries like retail, construction etc, the high risk, high value, long-term, co-dependent relationships to be found in Aerospace and Defence create the ideal conditions where collaboration should be most effective. If these conditions can be exploited, the industry as a whole would be well poised to develop the collaborative relationships needed for Industry 4.0 implementation to be successful.

With the increased automation and augmentation of tasks and decisions, traditional Procurement and Supply Chain roles are under threat. Despite this, a growing need for Procurement and Supply Chain to act as a strategic value driver and effectively apply higher-order skills like creativity, complex problem solving and emotional intelligence provides a promising future for those willing to adapt in the function and will enable a future in which Buyers and Supply Chain professionals will operate as strategic business contributors, empowered to act dynamically in an data rich interconnected environment.

There are many barriers to the realisation of Industry 4.0 however chief amongst these are concerns over cyber security, a shortage of digital skills and conceptual issues over what the objective of Industry 4.0 is and how to achieve it. Developing adequate cyber defences is a technical issue and it is conceivable that measures will be found to counter new threats; for a skills shortage, there is simply an upskilling/reskilling requirement. For both, the path to resolution is clear. Lingering questions over the fundamental objectives and means of effective implementation have the potential to have more pernicious effects on organisations, for to invest without reasonable surety of outcome or a well understood means of approaching the task is a recipe of disaster. What is clear is that the introduction of SMART factory capabilities will prove to be a competitive differentiator for some early adopters, for others, an expensive exercise that does not achieve its goals; but for the followers, it shall become a means of survival. Whilst these changes may seem drastic and slightly overwhelming today, that is the nature of Industrial Revolutions.

ABOUT THE ADPG-NEXT GENERATION GROUP

The Aerospace and Defence Procurement Group ('ADPG') is an industry group consisting of senior Procurement and Supply Chain representatives from key Original Equipment Manufacturer, Tier 1 and Prime organisations from the UK Aerospace and Defence industry.

Facilitated by the Chartered Institute of Procurement and Supply ('CIPS'), the ADPG seeks to drive excellence and professionalism within Procurement and Supply Chain through industry wide initiatives designed to act as a catalyst for best practice sharing, skills development and growth in professional expertise.

The Next Generation ('NG') Group consists of a number of young Procurement and Supply Chain Professionals selected by each ADPG member from their respective organisations. The NG Group supports the development and implementation of ADPG initatives and proactively looks to provide insights to the ADPG and the organisations they represent on topical issues affecting the future of the Procurement and Supply Chain function.

The NG members that have authored this Industry 4.0 Report are:

James Morse (NG Chair)	Vivienne Steeds
Stewart Boyd	Connor Welsh
Matt Smith	Jamie Mackay
Jonathan Tavernor	Jack Grimwood
Matt Eagle	Ben Wilberforce Ritchie
Michaela Bousfield	

If you would like to contact us, please send us a message on our facebook page, just search: *ADPGNG*

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