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Contents Page:

Section 1: Introduction.....	Pages 3-5
1.1 Aim and purpose of the paper	
1.2 Structure of the document	
1.3 Case study and areas of research	
1.4 Defining industry 4.0 and its relevance	
1.5 Prerequisites for adoption	
Section 2: Main Content.....	Pages 5-9
2.1 Analysis of case study – current state	
2.2 Industry 4.0 – rate of change	
2.3 Industry 4.0 – existing and emerging technologies	
2.3.1 Internet of Things and cloud computing	
2.3.2 Simulation and augmented reality	
2.3.3 Additive manufacturing (3D printing)	
2.3.4 Big data analytics	
2.3.5 Cyber security	
2.3.6 Artificial intelligence and robotics	
Section 3: Conclusions and Recommendations.....	Pages 10-12
3.1 Opportunities presented	
3.2 Risks and challenges of implementation	
3.3 Recommendations	
Section 4: References.....	Pages 13-14
4.1 List of references	

Section 1: Introduction

1.1 Aim and purpose of the paper

The purpose of the paper is to investigate current manufacturing systems evaluating their effectiveness at an abstract level. This involves identification of the possible areas in which new and emerging technologies may be utilised to adapt these processes and practices. The paper provides a detailed analysis of the current technological factors that afford beneficial impact in addition to any humanistic or environmental implications of such adoptions. In improving efficiencies, any economic and or societal benefits to the implementations will need to be considered.

1.2 Structure of the document

The paper begins with an introduction of an appropriate case study. This has been identified in order to provide an example of a manufacturing system for analysis purpose and to better illustrate some of the more unique problems that may be encountered and resolved with the employment of emergent technology. An outline of the areas of research undertaken follows; providing arguments and justification for supporting and conflicting evidence which has been reviewed. The introduction of the paper also looks to define industry 4.0 and consider its impact on a manufacturing organisation as a whole. To conclude the section, prerequisites for adoption of industry 4.0 are discussed.

The main contents of the paper starts with details of the case study – the focus of which is Bisley (F C Brown) Steel Equipment Ltd and the various aspects of its manufacturing facility. Bisley cannot be defined as an SME, due to the fact that it has more than 250 employees worldwide, and a turnover of more than 50 million euros (European Commission, 2022). Despite this however, many similarities can be drawn between the opportunities presented but also the challenges and risks faced through the deployment of these emerging technologies. The main section of the paper demonstrates how key technologies act as determinants of industry 4.0 adoption and the effect this could have on the overall business in the future.

Within the third section of the paper, the opportunities presented by industry 4.0 are discussed. Providing justifications for potential benefits in terms of financial, societal, and environmental success. Conversely, the limitations, risks and challenges faced by manufacturing organisations are also considered. The paper concludes with recommendations for businesses, industry, and governing bodies, followed by a list of references.

1.3 Case study and areas of research

Bisley is a large manufacturing organisation based in Newport, South Wales. Established in the 1940s, traditionally the company specialises in steel office storage products. However, the brand has more recently diversified in both its product ranges and market reach. As customer requirements have become more complex, the business has invested in its capability to also manufacture wooden products. These capabilities allow the combination of finishes, materials, and components to create an enhanced storage solution. The company now serves not only the office furniture market, but also healthcare, residential and hospitality.

Its focus is on creating innovative products that meet the evolving needs of our working world (Bisley, 2021). Bisley has just one manufacturing site – although sells products all over the world, including North America, Dubai, France, Netherlands, and the UK. There are three dedicated sales channels – one focused on selling products through a dealers and resellers networks, another which sells directly to corporate clients. Over the past five years, the company has provided solutions for large clients

such as JP Morgan Chase, HM Revenue and Customs, British Telecoms and Royal Bank of Scotland. The company also sells products directly to consumers through an online web shop. Here, individuals can order products for their home working environment, typically in much smaller volumes than the traditional corporate business.

The research undertaken for this paper consists of various elements as the topic of industry 4.0 is broad and complex. As well as fundamental information regarding determinant technologies, research for this paper also considered the impact of industry 4.0 on the business model development, the approach to innovation and financial planning, lean manufacturing principles and its impact on other environmental and societal initiatives. Research was conducted through analysis of various sources, including journal articles, conference proceedings and industry-driven research papers. As (Yang F., 2021), suggests, industry 4.0 is still in its infancy. It is in a conceptual state which intends to integrate very large number of dynamic technological concepts. Information included must be up-to-date and relevant.

1.4 Defining industry 4.0 and its relevance

The term industry 4.0 is commonly interchanged with the fourth industrial revolution. Many including (Powell, 2021) suggest that digitalisation of manufacturing is the essence of industry 4.0 realisation. It presents a new era in the organisation and the control of the industrial value chain. Industry 4.0 represents production networking and the digitalised connectivity between suppliers and customers across the complete value chain. Three key elements include high grade digitalisation, smart manufacturing through cyber-physical systems and inter-company connectivity between suppliers and customer across the entire value eco-system (Muller, 2018), (Kohtamaki, 2020).

(Deloitte, 2021) defines an eco-system as a web of mutually beneficial relationships brokered by a digital platform that enhances economic value for all. “Smartness” is the ability to communicate and co-operate in real-time. Autonomous decision making to steer oneself based on information obtained (Weking, 2020). Cyber – physical systems (CPS) are composed of physical hardware, software, and human intervention Each of these elements are integrated closely and networked to deliver some global behaviour (Grabowska, 2022). Working together more effectively within a range of operational technologies. “Interoperability” is the ability to communicate, share digital assets and data (Grabowska, 2022). Industry 4.0 spans across the entire organisation – it is not limited to the manufacturing or production department; its implementation needs to be managed and organised from the very top of the company; throughout all departments; with all employees.

1.5 Prerequisites for adoption

A business model describes the rationale of how an organisation intends to create, deliver, and capture value (Ibarra, 2018). A business model underpins value proposition, market segments, structure of value chain, value capture mechanisms and how these elements link together (Weking, 2020). On the other hand, a business strategy is required to create and appropriate value from the organisation’s systems, processes, resources, and competencies (Kohtamaki, 2020). Operational adjustments can be made to identify new avenues and sources of value. One of the most important prerequisites for implementation of industry 4.0 is understanding value – and what manufacturing processes or product features add value from the customer’s perspective (Powell, 2021). It is important

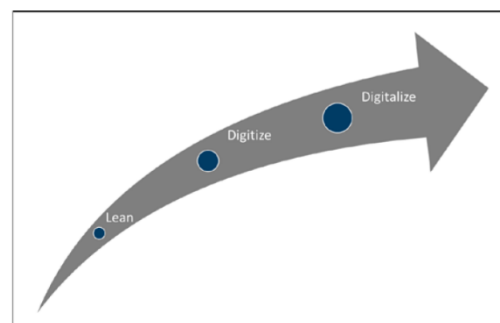


Fig. 1. The Lean First... Then Digitalize Approach

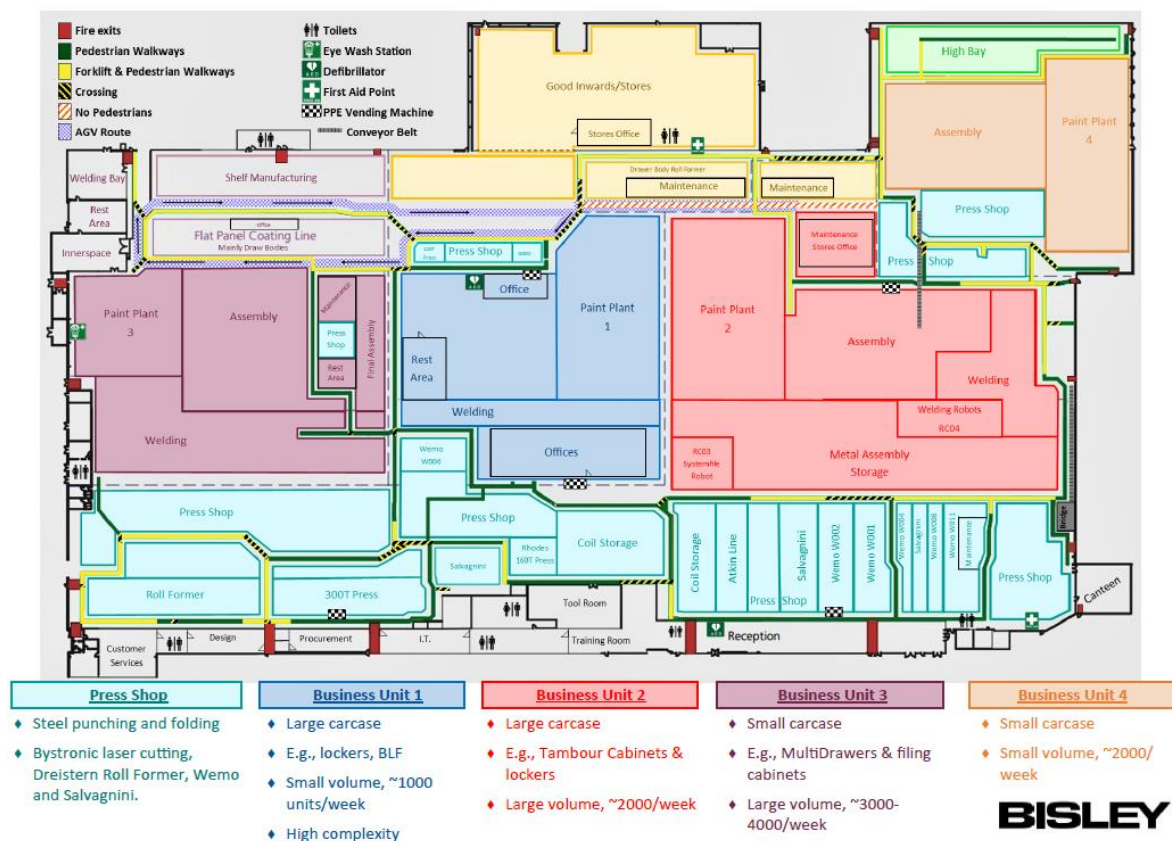
Fig 1. The Lean First... Then Digitalize Approach (Powell, 2021)

that much like sources of finance or methods of innovation, companies realise that one approach to adopting industry 4.0 does not fit all. In a similar way to lean manufacturing principles demonstrate methods need to be controlled through planning, doing, checking, and acting (Sven-Vegard Buer, 2018). Continuous improvement should be made in small incremental steps, whereby changes are reviewed and validated regularly (Nicholas, 2018). Other prerequisites are discussed in section three of the paper, but communication of the business model and strategy is critical to develop collaborative working and long-term thinking.

Section 2: Main Content

2.1 Analysis of case study – current state

As discussed in the first section of the paper – Bisley cannot be defined as an SME when considered as a complete manufacturing entity. However, if each of the business units, (or manufacturing systems) are considered in isolation; parallels can be drawn between the opportunities and challenges faced by many SMEs during the adoption of industry 4.0 technologies. Below is a map of the Bisley factory showing each of the four manufacturing systems. These have become well-established as the company has evolved over the decades. New products are developed with these embedded manufacturing systems, and process capabilities in mind.



Bisley Factory Map V4 PDF (Bisley, 2022)

Bisley has various types of manufacturing systems; starting with business unit one for example, this manufacturing system is designed to accommodate the most complex of products. Generally, the product variation through this system is very high, volumes of identical product tend to be small and the takt time and cycle time is high. For these products, typically parts are laser cut rather than hard tooled, and a prototype is often required as proof of concept before a production batch can be produced. Furthermore, a bill of materials needs to be generated for each product based on the specification provided by the customer and interpreted by the design and production engineers.

In contrast to this, business unit three is another manufacturing system within Bisley. This system however only caters for traditionally very high-volume products with low variation. For this reason, products manufactured here are relatively simple and much of the manufacturing process is automated. The cycle and takt time for these products is short, and typically these products are low cost. A comparison of the cycle times for some of these products are shown in the table below. The majority of the parts are cut using hard tooled presses which are machines fed by coils of steel. The folding, assembly, and welding of the product is highly automated using a conveyor and welding robotic arm. Many of these parts, and assemblies are manufactured in large batch which results in large inventory levels (Harris, Introduction to Industry 4.0 Essay, 2021).

Cycle Time (sec) Min	PP3				PP1							
	Multi Drawer			PP3 Contract Filing Cab	BLF							
	12 Series 5 Drw	29 Series 10 Drw	39 Series 15 Drw		10 Door Lodge	System Door Units	M6 System Tambour	2 Door Cup 2 Shelf	BLF 3 Drw Unit	CDF 4 Drw	DF 4 Drw	DF 6 Drw
	303	607	910		1826	780	871	928	1224	1069	1122	1237
	5.1	10.1	15.2	3.5	30.4	13.0	14.5	15.5	20.4	17.8	18.7	20.6

Comparison of cycle times (Lean Manufacturing UK Ltd, 2018)

These manufacturing systems have served the company well, allowing them to become leaders in process capabilities and product innovations within the industry. The main challenge for the company today, and over the next few years, is responding to changes in the market and customer demands. The steel furniture industry is declining; largely due to the advances in technology and the way that people work. For example, cloud computing means companies do not need to physically store large volumes of paperwork. Offices do not need the iconic multi drawer and desk for each employee, as hot desking and working from home means office environment need to be flexible and collaborative (Coach, 2020). As a result, the business has seen a downturn in sales of the traditional commodity products manufactured through business unit three. The company needs to innovate – in terms of capabilities and market segments. It is apparent that industry 4.0 technologies such as big data analytics could be used for data-driven decision making with regards to where to invest and provide resource to fulfil future customer requirements more effectively.

In a study carried out by Deloitte, the majority of the manufacturing companies surveyed agree that the digital transformation to industry 4.0 could boost Swiss industry's global competitiveness; 40% of respondents strongly agreed and a further 44% agreed that this was the case (Deloitte, 2021). However, within a study conducted by (Boston Consulting Group, 7th December 2016), the biggest challenge in implementing industry 4.0 was changing company culture and way of thinking. The same can be said for Bisley. Many companies are complacent in their ways and continue with an 'if it isn't broke don't fix it' attitude (Harris, Introduction to Industry 4.0 Essay, 2021).

2.2 Industry 4.0 – rate of change

"Around the world, traditional manufacturing industry is in the throes of a digital transformation that is accelerated by exponentially growing technologies. The pace of change reflects 'Moore's law' on the speed at which information technology-driven change happens. Research has shown that Moore's law – which states the capacity of microchips, bandwidth and computers doubles every 18 months, representing exponential growth – also applied to other technological developments" (Deloitte, 2021).

There are increasing pressures on manufacturing companies due to globalization. Customers are expecting more diverse, personalized, complex solutions with reduced lead times at lower cost. Manufacturers are faced with price increases due to raw material shortages, energy price increases and more volatile market demand. Competitive advantage is critical to maintaining a good share in the market. Manufacturing companies need to be agile and able to react to changing customer requirements, to build a sustainable and profitable company.

2.3 Industry 4.0 – existing and emerging technologies

(Platform Industrie 4.0, 2019) explores five drivers and/or enablers of digital business models: availability of core technology, digital elements for achieving operational excellence, big data, focusing on customer experience and marketing. Research undertaken presented that existing literature agrees that the various technologies can be used to drive, enable, or enhance industry 4.0. Much of the literature also suggests that these operational technologies are intrinsically linked. It is apparent that an ambidextrous approach to adoption is required to ensure that the core business is protected, and served with maintained quality, whilst also exploring new opportunities and sources of revenue. The difficulty is that whilst it is beneficial to implement some of these technologies in silo, to unlock the full potential of opportunities, a business' entire eco-system needs a paradigm shift in both its managerial and technical aspects.

2.1.1 *Internet of Things and cloud computing*

As the internet of things and cloud computing continues to develop, capabilities increase. This is with regards to the complexity of data that can be processed and the algorithms that can be calculated. Companies are able to combine data sets, to monitor and align different processes, all from one central location. The underpinning technology to enable this is sensors and microprocessors. Communication of machines improves the overall workflow of the system. In the example of the case study, this could be implemented to control the manufacturing of parts in the press shop, based on real-time data recorded from metal assembly. The investment cost for this technology is viable for most companies; the appeal is increased by the advantageous ease to up-scale. Another benefit of this technology is the reduced risk of data loss and privacy breaches. External expertise can be used to handle any failures and malicious actions.

The main barrier for implementation is the relevant skills and knowledge to take full advantage of the technology. As the value of analysed data increases, the risk to customer data and data privacy also increases. Data can be stolen, analysed, and traded for financial gain, and for capitalisation of market share. Companies need to have a clear IT strategy in place to help mitigate these risks. Investment is needed for secure data protection. The interaction between cyber systems and physical systems is still a relatively new concept, therefore there is some concern surrounding this. Manufacturing equipment present in the physical space has the potential to cause harm – vulnerability to malicious cyber-attacks needs to be considered. Remote changes can also push parameters outside of process control. Output quality may be affected by this, leading to various types of waste. This is an example of how IoT is intrinsically linked with cyber security.

2.1.2 *Simulation and augmented reality*

Using data-driven decision making based on what if scenarios is the major opportunity provided by this technology to optimise manufacturing systems. Real time simulation via a digital twin can provide feedback loops for adjustment of parameters. The efficiency of the products across their entire lifecycle can be improved. For example, simulation could be used to map the process of the electrostatic powder coating plant. Feedback in terms of powder coverage could prevent waste, but also optimise the powder thickness to ensure maximum protection for the product against oxidation, hence extending the lifecycle of the product.

This technology can also be used to engage with customers. Engagement can enhance the overall customer experience which develops partnerships, loyalty, and a better brand reputation. Instant feedback loops with customers avoids wasting resources on developing solutions which the customer does not value. Augmented reality brings a product to life, without the expense or waste of physically manufacturing anything! Virtual reality could be beneficial for training purposes, such as for new operators on a particular machine, or technicians for preventative maintenance of equipment.

Optimisation is generally defined as making the best or most effective use of resources. It is important that throughput does not overwhelmingly exceed demand though. Overproduction and overprocessing is waste. This can negatively affect the environment as well as having an adverse impact on the workforce. They are likely to become unfavoured towards change if benefits are perceived to be purely economically driven. It is crucial that Government policy is used to protect both the workforce and the environment in this regard.

2.1.3 Additive manufacturing (3D printing)

Additive manufacturing or 3D printing is a technique which can be used to prove a concept before a full production batch of parts is manufactured. It enables engineers to prototype parts quickly and at relatively low- cost. Components can be printed from the machine in-house, and tested for functionality, such as strength, fit and form. The major advantage is the time and expense saved from developing tooling. Very often with first batches, iterations are needed to improve or change the component slightly. This leads to further cost and delay to component availability. For example, Bisley uses various suppliers for small plastic components – due to the injection moulding process costs, there are very often minimum order quantities and lead time associated with this supply chain. Additive manufacturing can improve the company's flexibility as it is possible to produce a batch size of one, if necessary (Yi Wang, 2017).

Similarly, to IoT and cloud computing, new skills are required to maximise utilisation of this technology. Training may take some time, but employees can become more multi-skilled, and these skills can be transferrable across various projects. Additive manufacturing capabilities continue to expand and develop. Availability of 3D printers has grown leading to reduced prices. This makes them more accessible to companies of all sizes.

2.1.4 Big data analytics

Data can be collected to monitor the efficiencies of virtually all aspects of a manufacturing system. This can include anything from changes in customer requirements to the overall delivery performance. It is becoming increasingly easy to generate and store large volumes of data. This means that pattern recognition and data trends increase in accuracy. Integration into existing systems has been developed, making it less difficult. Service life of equipment can be extended for example as data can be used for preventative maintenance schedule deployment.

Overall equipment effectiveness considers the availability, performance, and quality of a system (Nicholas, 2018), therefore data analytics can be used to improve this in all aspects. Ensuring that processes are effective and efficient can help the company become more profitable overall. In turn, this can increase job security for everyone within the organisation. Big data analytics can evidence potential savings for the business and can be used to drive change, within a process, within the business culture, and employee's attitude. Data driven decision making can increase engagement of all employees; everyone understands the rationale behind decisions, and management through to shopfloor operatives can be involved.

There are opportunities for big data analytics to provide environmental benefits as well as economical and societal. There is increasing attention and a changing attitude towards the importance of the carbon footprint of any manufacturing systems. When this is implemented across many companies; throughout the entire manufacturing industry, this has a greater impact on the environment globally. Big data analytics can help ensure compliance with laws, regulations, and policies in this regard.

Data needs to be converted into useful information before it can inform decisions. It is imperative that the 'right' data is collected. "Garbage in equals garbage out" essentially means that the quality of results depends upon the quality of the input data. Information then needs to be interpreted to become useful. It is only then that the data collection is truly value adding. Data analytics needs to be autonomously integrated in a way in which it does not become a non-value adding activity within the process. Non-value activities and waste goes against the key principles of lean manufacturing methodologies which many manufacturing companies, including Bisley, have strived towards implementing for many years.

2.1.5 Cyber security

A consequence of the implementation of cyber-physical systems is the increased risk of cyber threat. In order to mitigate these risks, companies must consider investing time and financial resources. Techniques such as fail safe and air gaps are commonly implemented as they can be used to prevent attacks, however it is vital that these methods develop at the same rate at which cyber-attacks become more complex and diverge. Through data control, IoT and general increased "smartness" of systems, IT and cyber security is becoming a more substantial part of the manufacturing industry. As a result of this, there is likely to be an increase in these job roles, to ensure businesses have the relevant skills for the future. Bisley has recognised the importance of these skills within the business, and the IT department is expanding to reflect this. Apprenticeship and graduate schemes are a great way to ensure young people can gain and learn valuable skills.

2.1.6 Artificial intelligence and robotics

Robotics have been used within the manufacturing industry since the third industrial revolution (i-SCOOP, 2020). Although as more research, development and 'real-world' testing has been undertaken, the technologies have continued to advance. Technological advancements often increase versatility, meaning they are suitable for a wider range of applications. Examples of such improvements within robotics include the increased speed at which data can be input and the improved communication through feedback loop mechanisms. Consequently, artificial intelligence and robotics can provide opportunities to replace monotonous and potentially dangerous jobs currently undertaken by humans. Bisley takes advantage of this type of technology using robotic welding cells for the assembly of large carcasses. This process would be difficult and dangerous for an operator to undertake.

Despite these opportunities, there are also some risks associated with this type of industry 4.0 technology. Arguments can be made that robotics are dangerous for humans to work alongside. Unintended actions from robots could endanger others in the workplace, resulting from malfunctions or cyber-attacks. Due diligence is required by undertaking the necessary risk assessment and ensuring adherence to standards including ISO/TS 15066 (International Organization for Standardization, 2016). Big analytics could be complementary here to ensure that suitable preventative maintenance is in place to avoid unplanned downtime – leading to reduced OEE.

Section 3: Conclusions and Recommendations

3.1 Opportunities presented

The adoption of these industry 4.0 technologies present opportunities to innovate the business model. This begins with identifying the flaws within the current business model before implementing incremental innovation for improvement. There is a period where there is parallelisation of the old and new business models, whilst new ecosystems and value networks are established. A new business model can then be seen as disruptive or radical innovation for the business.

Product-service systems move from providing products, to add-on services and finally outcome, solution, or platform-based offerings (Kohtamaki, 2020). Product service systems can be sub-categorised further as life-long partnerships, product-as-service, or result-as-service (Weking, 2020). The first capitalises by using IoT-connected devices to add continuous revenue streams, throughout the entire product life-cycle, with subscription based, long-life service contracts. Networked eco-systems proposes the idea of sharing data through means of big data, cloud computing and artificial intelligence. The business must be more transparent with all stakeholders in the value chain (Ibarra, 2018). The concept of an eco-system rather than a value chain is that the data flow is circular rather than unidirectional, supporting the transition to a circular economy (Ren, 2019). There are environmental benefits too as supply and demand is synchronised to minimise waste. Customer-driven encompasses the desire to be innovative with new capabilities to explore new market segments. Typically, this type of business model uses an open innovation strategy to communicate directly with the customer. Crowdsourcing or mass customization are examples of open innovation. According to (Satell, 2017) and his innovation matrix, the less well defined the problem and the domain, the greater the risk. Generally, it is suggested that companies use the 80/20 rule, whereby the majority of the resource is used serving and exploiting the core market segment. The remainder can be used for breakthrough, disruptive innovation, or basic research. This is often referred to as ambidextrous innovation.

Throughout the paper, there are various examples of opportunities adopting these new and emerging technologies can present. Some of these opportunities are economically beneficial – but others are beneficial for society, the environment and for the manufacturing industry as a whole. Data driven decision making can be beneficial for prioritising investment. If funding and resources is limited, data can be used to validate and prove decision making. Likewise, data can help reduce the risk of investment as more accurate forecasting and return on investments can be calculated. Knowledge within the company can also be improved; this can be in terms of the customers the business is aiming to serve, the processes they are using or the industry as a whole through expertise of partnerships within the eco-system. There is opportunity for optimization; processes can be made most effective and efficient to suit the needs of the business. Real-time data means the business can be agile; management can be pro-active as opposed to reactive.

The paper has presented opportunities to move away from the traditional silo working of manufacturing companies, and others within its value eco-system. Technologies can be utilised to promote more transparent working, for example, to more closely monitor and react to changing customer demands, and raw material availability. As the threat of globalization becomes greater, this would help protect British manufacturing as a collective. Flexibility and agility in serving the customer base helps provide competitive advantage to ensure loyalty, and long-term business. Environmental opportunities include elimination of waste, this a common theme throughout lean manufacturing principles. Overproduction and overprocessing can be eliminated - IoT allows various systems to be interconnected. Demand can be monitored and controlled remotely in real-time. Simulation and 3D printing allows benefits the management of the product lifecycle. Finally, customer-driven business models can promote frugal innovation – customer requirements are fully understood without the need for over-engineered, complex solutions which are not designed for manufacture.

Societal opportunities include a strive towards a more flexible, problem-solving workforce. Communication of business strategy is important to ensure inclusion and clarity towards working for a common goal. Employees become more open minded towards change; they are enthused by the challenge to upskill, rather than fearful of redundancy through innovation. Ideas and thoughts of all employees, from management to shopfloor should be heard and considered. Industry 4.0 ideology in this respect provides opportunity for dynamic, long- term thinking. There is loyalty, respect, and dedication towards achieving the best for the company as a whole.

3.2 Risks and challenges of implementation

Digitalisation paradox refers to the high investment, challenging implementation and integration faced by many businesses. Investment is needed to reduce the cost of data processing by automizing. The relationship between digitalisation and performance are non-linear and complex. Complementary capabilities and organisational practices may also need investment in terms of finance and time. Return on investment relies upon value creation and value appropriation (Kohtamaki, 2020) (Harris, Advanced Industry 4.0 - Written report, 2022)

Sociotechnical perspectives refer to the entanglement between technologies and society. Complexity requires a higher level of competency. It can be costly to train employees and takes time for change to become imbedded within an organisational culture. Considerations need to be made towards this when calculating the investment and payback period (Platform Industrie 4.0, 2019), (Kohtamaki, 2020) (Harris, Advanced Industry 4.0 - Written report, 2022).

There is also a risk that companies overlook the opportunities presented by industry 4.0 for they fear it too complex or time-consuming. Both additional training and support is needed, especially for smaller organisations, so that they can understand and be pro-active in their approach to implementing industry 4.0 incrementally. Due to the literature surrounding industry 4.0, the “paradigm shift” and “radical innovation” to manufacturing can seem daunting. It is necessary to manage expectations, that improvement and change takes commitment in terms of time and learning by doing.

One of the greatest challenges for the industry is that whilst opportunities may favour those who are prepared; pro-active, ambidextrous approaches will look different from company to company. Industry 4.0 is intended to build upon some key elements of the industrial revolutions and manufacturing principles that have come before (i-SCOOP, 2020). For the manufacturing industry to progress as a whole, large businesses need to support those smaller than themselves within their eco-system to seize opportunities as a collective.

3.4 Recommendations

To conclude this paper, it is recommended that Bisley strives for improvements towards the communication of its business model and strategy to all departments and employees. It can be difficult to understand the rationale of decision-making if the direction of the business for the future is not well understood. This would improve collaborative working between departments to achieve a common goal. Likewise, data and knowledge sharing could be improved to increase interoperability throughout the business.

It is also recommended that more support is made available by Government and regulatory bodies for companies such as Bisley to understand the opportunities presented by industry 4.0, not only for their future business, but for the entire networked eco-system. Laws such as civil, product liability and data protection laws need to be updated as technology advances and becomes more accessible (Platform

Industrie 4.0, 2019), to ensure the risk of transparency does not discourage data feedback loops and encourage data exploitation.

Finally, for Bisley it is recommended that industry 4.0 technologies are fundamental in the development of the wood manufacturing system. The case study has demonstrated that legacy product and systems can introduce limitations on innovation. As these manufacturing capabilities are relatively new to the business, there is opportunities to exploit new areas of potential growth for the company.

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