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An Evaluation of Industry 4.0 Implementation for Low Digital-Maturity SMEs.

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Introduction

Society is experiencing uncertain times. The pandemic has shown companies the need to be agile to create resilience (Bianchini and Kwon, 2021, p.34; Office for National Statistics, 2022). Resilience capabilities require a company to prepare for unexpected disruptions, enabling rapid responsiveness and adaptability, and seeking improvement opportunities in adversity (Bianchini and Kwon, 2021, p.10). McKinsey & Company's survey of current global economic performance suggests that surveyed economies are recovering well from the impacts of the pandemic (FitzGerald *et al.*, 2022). However, the effects on economic growth continue, along with the addition of high inflation and Russia's war with Ukraine (FitzGerald *et al.*, 2022). Global trade levels are buoyant but rising global energy prices are further impacted by uncertainty of supply availability (FitzGerald *et al.*, 2022). These current financial strains, coupled with increased taxes, wages, and cost of goods, are creating increasing operational costs, presenting challenging pressures for business sustainability (ACCA, 2022). These factors may prohibit business growth and therefore, it is crucial for SMEs to build resilience to mitigate impacts from these ongoing risks. This may be challenging, but of paramount importance, for SMEs with limited resources, and can be aided through use of accessible digital technologies (Bianchini and Kwon, 2021, p.10). Industry 4.0 (I4.0) facilitates this by creating transparency in specific functions and processes throughout the business (Gilchrist, 2016, p.206), including digital systems and processes, embracing digital marketing, and developing agile capabilities, to reflect customer demands and achieve relevance and success within the market (Forbes Coaches Council, 2021).

Global environmental concerns are another current key consideration for SMEs. The Welsh Government is requesting businesses contribute towards Net Zero targets (Welsh Government, 2021) and greater awareness in SMEs of how this can be done is required for greater engagement (Ri, 2022). Although individually SMEs may not greatly increase Greenhouse Gas (GHG) emissions, the volume indicates that collectively they may make up half of that caused by business operations in the UK (Ri, 2022). Whilst not a proven connection, research indicates that proactive environmental actions by businesses are seen alongside growth in SMEs (Ri, 2022). In fact, working towards Net Zero can simultaneously create additional business benefits (Business Wales, 2022). Cost reduction, brand reputation, and responding to customer demands are all indicated as drivers of more impactful environmental improvements in businesses (OECD, 2021, p.6; Ri, 2022). I4.0 methodologies can aid sustainable development in businesses through enabling resource efficiency and waste reduction (Brozzi *et al.*, 2020). Further, the capture of data facilitated through I4.0 technologies creates greater transparency across the value chain for improved efficiency and monitoring of product manufacture (Brozzi *et al.*, 2020).

The development of increasing technological advances creates great opportunities for businesses today (Fachrunnisa *et al.*, 2020). For SMEs whose level of digital maturity (Amaral and Peças, 2021) may be low, adopting even incremental digital transformation will likely prove extremely beneficial for business sustainability (Martinez, 2019) and vital to mitigate future unexpected risks (Bianchini and Kwon, 2021, p.10), whilst remaining relevant and competitive in consumer markets (Fachrunnisa *et al.*, 2020, Forbes Coaches Council, 2021).

Therefore, the key concepts this essay will explore are:

- The importance of adopting digitisation in low digital-maturity SMEs (LDMSs) for business longevity.
- How I4.0 can aid LDMSs in developing agile capabilities, to increase their resilience.
- The opportunities I4.0 methodologies present for business improvement to facilitate growth.

This essay will discuss some of the I4.0 methodologies that could prove beneficial to LDMSs, reflecting challenges posed by the current global landscape, and evaluating their benefits and considerations in implementation. The essay does not seek to provide specific guidance for LDMSs but to present an introduction to methodologies for consideration in relation to individual organisational context.

Introduction to Industry 4.0 (I4.0)

The premise of I4.0 is that enabling the digitalisation of data facilitates improved collation and analysis of that data, creating information that can be communicated and decentralized, resulting in increased knowledge for agile decision-making (Moeuf *et al.*, 2018; Amaral and Peças, 2021). As digital technologies are developing at an ever-increasing rate, so too do the characteristics of I4.0 continually evolve (Ghobakhloo, 2018). Features of I4.0 implementation include data capture and analytics, sensor technologies, and use of intelligent software and machines (Gilchrist, 2016, p.242).

I4.0 methodologies can provide many benefits to LDMSs in the current global landscape. Utilising digital technologies can prompt innovation skills development, and can facilitate international trade through interconnected communications, furthering market reach (Gilchrist, 2016, p. 238; Fachrunnisa *et al.*, 2020). Efficiency of processes, facilitated by enhanced information visibility, leads to reduced costs alongside increased output, enabling improved customer service and competitive advantage (Gilchrist, 2016, p.205-206, Martinez, 2019). Digital technologies can aid the monitoring and management of environmental sustainability goals, such as smarter energy use and reduced emissions, and improved quality and resource efficiencies – relating to waste reduction – are perceived as major benefits (Brozzi *et al.*, 2020). All these factors point to the positive impacts of adopting increased digitisation.

The Process of Digitisation

Since the emergence of the pandemic, there has been an acceleration in digital technology adoption in businesses, which is cited as a strategic competitive differentiator (Galvin, LaBerge, and Williams, 2021). The process of transition to digital technologies may appear insurmountable to LDMSs due to the potential vast operational changes and infrastructure involved (Ghobakhloo, 2018). However, digital technologies adoption and capabilities in SMEs are cited as key strategy developments for business sustainability (Fachrunnisa *et al.*, 2020; Forbes Coaches Council, 2021). Keeping pace with developments and successfully ascertaining the best methods for the business context are important to remain competitive (Fachrunnisa *et al.*, 2020; Forbes Coaches Council, 2021). A lack of specific guidance available in industry for creating a successful path towards implementing I4.0 methods, could be a barrier to adoption (Martinez, 2019), which could present a greater challenge for LDMSs where research resources may be minimal (OECD, 2021, p.6). The challenge is whether the business has both the human and financial resources to enable adaptation, and adoption of new methods and technologies.

Enabling data flow, a central theme in I4.0 (Moeuf *et al.*, 2018), can be achieved through a variety of tools and methods which are scalable within the scope of the LDMS's existing processes. Availability and visibility of information in the organisation, gained through digitisation and data capture, enables rapid responses and decision-making for increased operational agility (Gilchrist, 2016, p.206). The costs and expertise required for implementation can vary (Moeuf *et al.*, 2018) and so an assessment must be made of the specific business needs, and whether improvement would be achieved through technology adoption (Martinez, 2019). The ability to perform diligent research on the available

technologies, and to assess the best route to adoption within the company's competencies and capacity, is an important strategic factor (Ghobakhloo, 2018).

Conducting an internal audit of the technology, skills, and infrastructure required for proposed I4.0 implementation will allow the LDMS to determine any shortfalls in these, and assess the resources required to bridge the gaps, before committing to developments (Ghobakhloo, 2018; Amaral and Peças, 2021). This assessment could simultaneously highlight opportunities for further development (Amaral and Peças, 2021). In LDMSs, it is likely that there will be a skills gap, but utilising the internal knowledge of employees, from experience of working in the company, alongside specific upskilling as required, will prove valuable to the process of transition (Ghobakhloo, 2018).

The organisational culture regarding receptivity of change is cited as a key determinant in successful transition to process digitisation (Martinez, 2019; Amaral and Peças, 2021). LDMSs may feel discouraged by the holistic approach required to fully implement digital transformation, fearing the culmination is beyond their scope (Ghobakhloo, 2018). Therefore, strong agile leadership skills are vital in LDMSs working towards digital transformation, for decision-making and engagement of the employees (Fachrunnisa *et al.*, 2020). The following sections introduce some methods of digitisation and discusses their suitability for adoption by LDMSs.

Cloud Computing and Big Data

I4.0 methods can be utilised across business departments, so all business areas should be explored for positive impacts from digital transformation (Gilchrist, 2016, p.232). The collation of digital data from across functions and processes enables managers to visualise the performance and knock-on impacts of all operations, and to adjust accordingly (Gilchrist, 2016, p.236; Moeuf *et al.*, 2018). Cloud computing provides a platform within which data can be digitally stored and communicated, creating a pool of information from which to draw understanding (Wang *et al.*, 2016). Developments in big data analytics enable businesses to make sense of this vast data pool, to facilitate better-informed decision-making in real-time for greater agility (Ghobakhloo, 2018). Data mining is the process of analysing the collated data, which can be achieved through AI, involving algorithms and deep learning to identify trends, and statistics, as a mathematical modelling approach (Han and Trimi, 2022). Data mining creates a vital opportunity for companies to extract useful information, increasing visibility of processes within the business operations, aiding efficiency (Ghobakhloo, 2018).

Accessibility of information benefits LDMSs as limited resources require efficient planning and management (Moeuf *et al.*, 2018; Amaral and Peças, 2021). Global factors and wider information can improve the analytical process (Gilchrist, 2016, p.238) by increasing the spectrum for consideration. However, whilst technology developments have enabled increased capture, storage, and analysis of data, it is not necessary or relevant to collect all data possible. Strategic decisions need to be made on the data requirements which best facilitate improvement in each individual context (Wang *et al.*, 2016; Moeuf *et al.*, 2018). Developing a system with key team players, benefits optimal information gathering and engagement for implementing change (Martinez, 2019), and can build on existing knowledge whilst further developing in-house skills (Moeuf *et al.*, 2018).

Evidence suggests that a holistic approach to digital developments is required throughout the business to attain true success (Shumpei and Mihail, 2018). Therefore, elimination or

minimisation of silos in the business is required for successful full digital transformation (Gilchrist, 2016, p. 233) to create a seamless system. Cloud Computing is a common I4.0 methodology adopted in SMEs, as it is a widely accessible technology (Moeuf *et al.*, 2018; Bianchini and Kwon, 2021, p.10), beneficial for planning and communication within and outside the company (Moeuf *et al.*, 2018). Utilising cloud computing is cited as incrementally beneficial to operational performance in SMEs, as it improves communication throughout the organisation, thereby dispersing silos, whilst requiring minimal investment and expertise (Moeuf *et al.*, 2018).

The increasing development of internet-based applications and platforms, available through cloud computing, enables accessibility to some digital tools for LDMSs (Bianchini and Kwon, 2021, p.13). For example, the emergence of Software-as-a-Service enables businesses to utilise cloud-based software, normally on a subscription basis, increasing the flexibility and availability in accessing tools to suit the changing business needs, without weighty initial investment (Bianchini and Kwon, 2021, p.8; Han and Trimi, 2022). However, an awareness of complete service costs is essential to avoid spiralling expenditure (Bianchini and Kwon, 2021, p.13), which may not be considered at the outset. This reiterates the importance of research and awareness when embarking on digital developments. Additionally, with the increasing intertwining of physical and digital worlds, cyber security is of escalating importance in businesses adapted to I4.0 and it is suggested that there is further work needed in developing specific security for the various I4.0 methodologies (Han and Trimi, 2022). Research suggests that awareness of cyber-security risks in SMEs is lacking and tends to be a lesser-priority focus area (Moeuf *et al.*, 2018; Bianchini and Kwon, 2021, p.12), potentially leaving businesses vulnerable. Gaining greater knowledge of how to mitigate cyber-security risks should be of utmost importance for LDMSs in developing their strategy, for protection and to dissolve any barriers to digitisation relating to these risks.

It is reported that SMEs are not capitalising on the benefits big data can provide in increasing competitiveness, due to the challenges of managing analysis (Han and Trimi, 2022). The live data reporting that can be achieved through digital data systems facilitates agile decision-making and action, and therefore agile management capabilities are key skills required for LDMSs to fully reap benefits (Han and Trimi, 2022). Cloud computing is likely used currently in LDMSs for some business functions, and therefore to increase adoption of cloud computing applications should be an achievable goal. Expanding awareness of the opportunities accessible through cloud computing and big data, which may include investment in expert consultancy for guidance, will facilitate informed decision-making in the route to increased digitisation.

Data Analytics and Market Sensing

Businesses worldwide are facing increasing demands from customers to improve on product quality, price, and flexibility in their operations, and must respond accordingly to remain competitive (Shumpei and Mihail, 2018). Increased purchasing in manufacturing industries since the pandemic suggests growth, reflected in encouraging retail sales (FitzGerald *et al.*, 2022), although the OECD Consumer Confidence indicator suggests present uncertainty (FitzGerald *et al.*, 2022; OECD, 2022). Consumers are currently challenged by the increasing cost of living (FitzGerald *et al.*, 2022) and the business strategy should prepare for the impact this could have on future sales.

Incorporating technological advancement into the business strategy is key to future sustainability, with awareness of industry developments and their potential benefit to the company's operations instrumental within this (Ghobakhloo, 2018). The development of competencies in big data analytics will enable LDMSs to fully benefit from the information that can be extracted, useful in both operational and market sensing functions (Han and Trimi, 2022). Alongside developments in digital tools for manufacturing, digital marketing is growing, accelerated by the onset of the pandemic (Balis, 2021; Bianchini and Kwon, 2021, p.10). The transparency gained through social media interaction, creates valuable information that can aid companies in sensing trends and gathering feedback, utilising data capture technologies and analytical software (Ghobakhloo, 2018). Advantages are gained in marketing functions via acquired knowledge of customer behaviours, needs, and wants, informing marketing and product development strategies (Ghobakhloo, 2018). Strategic use of big data can support growth in LDMSs through improved trend predictions and increased market responsiveness, enabling diversity in product offering for market segments (Han and Trimi, 2022). Developing and drawing on these capabilities, alongside increased operational agility, will increase resilience towards fluctuations in markets and improved product offering (Ghobakhloo, 2018).

Made Smarter (Made Smarter, 2022) reports on a case study utilising big data and analytics: a print company manufacturing cut outs of celebrities and franchise characters. The SME invested in AI analytics software, which collates information from media, identifying trends on public commentary. The software produces live reports on fluctuations in persona trends, informing agile decisions on product development. Global information gathered by the software also enables the company to focus marketing within specific geographical segments for targeted sales. The company anticipates utilising the software will boost sales, expanding global reach, and steadily increase revenue, and are investing in automated machinery to increase production to meet demand. Upskilling the work team in digital skills development is an additional resultant benefit.

This development has required financial investment, but the projected gains in market expansion and sales growth suggest a worthwhile return. The ability to increase responsiveness to specific customer demands, creates a better customer service (Shumpei and Mihail, 2018; Forbes Coaches Council, 2021) and reduces waste through informed management of product development, reducing costs. The case study demonstrates that significant investment in targeted functions can yield positive financial returns for SMEs and enable growth. Implementing digital technologies will require and facilitate digital skills development (Gilchrist, 2016, p.205-206; Fachrunnisa *et al.*, 2020), which lack thereof is cited as a barrier to digitisation in SMEs; this therefore should be factored into the business strategy (Ghobakhloo, 2018; Bianchini and Kwon, 2021, p.12).

Data transparency and Sustainable Supply Chains.

Global supply chains continue to be disrupted by the pandemic due to transport delays, elevating costs (FitzGerald *et al.*, 2022) and impacting supply of raw materials (Office for National Statistics, 2022). The impacts of both Brexit and the pandemic have led UK businesses to create more resilient supply chains to ensure future stability (Office for National Statistics, 2022). Reducing costs and enabling greater agility in responding to changing customer demands are key objectives (Office for National Statistics, 2022). It is reported that some businesses have responded to these challenges by changing suppliers

and building higher stock levels (Vukićević *et al.*, 2021; Office for National Statistics, 2022). However, this has the resultant impacts of tying up finances in stock and risk of inventory becoming superfluous (Vukićević *et al.*, 2021). Digital data can aid improved stock monitoring by increasing visibility of information for use in decision-making (Moeuf *et al.*, 2018), and creating agile and efficient inventory management processes (Gilchrist, 2016, p.235). Exploring I4.0 methods with the objectives of cost and lead-time reduction may prove beneficial in LDMS business strategies (Moeuf *et al.*, 2018), as competitive advantage could be gained through improved customer service offering. Further differentiation could be gained through seeking methods for improved quality (Moeuf *et al.*, 2018), presenting dual opportunity for optimising brand reputation and working towards sustainability goals, for example in relation to perceived quality in long-term functionality of the product as well as its' manufacture.

Research suggests around 60% of global consumers place increased value on sustainable products, potentially providing increased market opportunities for SMEs and an incentive for actioning environmental sustainability goals (OECD, 2021, p.17; 19). I4.0 technologies facilitate collaboration for SMEs throughout their supply chains (Han and Trimi, 2022), for example by facilitated information sharing via cloud computing platforms (Han and Trimi, 2022). This data transparency may aid businesses in monitoring sustainability metrics across complex supply chains (Bianchini and Kwon, 2021, p.11; Galer, 2022). Digitised data facilitates collation and analysis, for example through use of sensor devices for emissions tracking; increased visibility and decentralisation enables conscious supply chain choices (Bianchini and Kwon, 2021, p.11). This can aid management in ensuring company values are maintained in internal operations and throughout the supply chain, which in turn can enable transparency with customers.

Blockchain technologies can be applied to any digitised information and enable data accuracy and protection (Ghobakhloo, 2018). Distributed Ledger Technologies, the basis for blockchain, are being developed for use beyond cryptocurrency for applications including supply chain management and traceability (OECD, 2021b). Decentralised information storage technology creates a transparent and unalterable data log for reliable, protected data recording and sharing (OECD, 2021b), which can facilitate the transparency and reliability of information sharing across the supply chain (Ghobakhloo, 2018). Increased accessibility of blockchain technology, for example, through third-party cloud-based platforms offering Blockchain-as-a-Service, enables SMEs to access benefits from the technology in development without committing large investment or requiring advanced expertise (OECD, 2021b).

However, the deficit of digital skills in SMEs alongside low awareness of such technologies are cited as barriers to adoption of blockchain. Additionally, blockchain technology requires digital data, and therefore necessitates the use of digital technologies within the business function to allow the technology to be applied. This creates another barrier for LDMSs for whom this is not the case. Despite the opportunities for blockchain technology in supply chain management, the interoperability between elements of the supply chain required for its successful vertical application is still widely in development (OECD, 2021b).

An example of digital technology under development for this function is the UKFT's Sustainable Supply Chain Optimisation project (UKFT, 2021). The pilot platform combines Blockchain, AI, and Cloud technologies to facilitate data sharing in textile supply chains, made possible through industry collaboration, integrating the textiles and ICT sectors. The platform's objective is to enable the informed development of more sustainable supply chains and product manufacture, through information transparency throughout the value

chain. The collation and decentralisation the platform is designed to enable will facilitate trust, waste reduction, and awareness of ethical practices in the industry, creating greater empowerment for suppliers, manufacturers and customers.

Such technology could provide positive sustainability benefits for LDMSs, through increased supply chain knowledge for conscious decision-making and the potential to promote business sustainability practices. The availability of live data would also enable rapid identification of supply chain disruptions, enhancing the business' capacity for agility and increased resilience (UKFT, 2021). As blockchain technology continues to develop across business functions, the future opportunities presented for business innovation should be seen as an impetus for LDMSs to increase their knowledge and skill set in readiness for future innovations in blockchain (OECD, 2021b), enabling their opportune uptake to remain competitive.

Sensor technologies for predictive maintenance.

Equipment maintenance is a key element in enhancing sustainable manufacturing processes, as the costs and capacity impacts associated with downtime can negatively affect profitability and service delivery (Chuang *et al.*, 2019). Sensor devices can be employed to monitor elements of machine performance and the surrounding atmosphere, to identify anomalies and faults (Moeuf *et al.*, 2018). Identifying relevant big data and creating digital data process systems will facilitate continuous improvement, by identifying trends, enabling better predictions to avoid unnecessary downtime and waste, improving operational efficiency and flexibility (Ghobakhloo, 2018; Moeuf *et al.*, 2018). The greater the volume of relevant data over time and the types of data being collected, enables a more detailed analysis of possible failure, enhancing accurate predictability (Chuang *et al.*, 2019). For example, data on environmental changes, such as humidity and temperature, could provide additional insights into the impact of variations in these.

Predictive maintenance uses information from data to target specific machine maintenance, helping to reduce costs associated with prescribed maintenance activities common to standardised service schedules, which are often practised in SMEs (Budinska and Dolatabadi, 2021). Using software to collate and analyse big data recorded by sensing devices minimises the time constraints of workers in performing this function (Chuang *et al.*, 2019), freeing them to undertake digital skills development for newly created digitised roles such as monitoring, systems maintenance, and supervision (Gilchrist, 2016, p.205-206). Digitisation may replace some human roles but creates opportunities for professional development and job advancement, rather than losses. This route aids company growth and resilience as talents, skills, and knowledge are increased in business functions, facilitating innovation and job creation.

Despite the benefits, high investment costs for implementation and maintenance of the system could prove challenging for LDMS adoption. Creating a coherent predictive maintenance system involves a complex system of interconnected devices and software, the scale of which could be challenging for LDMSs, and requires effective integration of all parts for reliability (Budinska and Dolatabadi, 2021); skills and management are required to support this. Companies should consider the technology requirements for their specific strategic goals, assessing whether they have the necessary infrastructure and capabilities to support the specified development (Amaral and Peças, 2021).

For a predictive maintenance system, adaptations to the environment may be required to mitigate any factors which could interfere with the reliability of devices, and resultant impact on system accuracy. Additional costs may be incurred, and new processes established to incorporate the new technology system (Budinska and Dolatabadi, 2021); these are key considerations for implementation. Reliance on predictive maintenance systems could create vulnerabilities in LDMSs due to uncertainty of prediction accuracy and where upskilling the work team may inadvertently result in a loss of knowledge and skills in traditional maintenance awareness (Budinska and Dolatabadi, 2021). For LDMSs to mitigate this risk, it may be prudent to integrate digital skills development alongside traditional knowledge transfer, to preserve these key skills.

Uncertainty regarding return on investment is cited as a barrier to digitisation in SMEs (Budinska and Dolatabadi, 2021; OECD, 2021, p. 23). This is a particular challenge for LDMSs (Budinska and Dolatabadi, 2021), as resources required to upskill employees and implement new technologies may appear vast. In considering implementation of a predictive maintenance system, the company should identify where investment is most required and would lead to the most beneficial outcome, to keep expense low and achieve maximum return (Moeuf *et al.*, 2018), for example, targeting specific metrics or machines where regular performance issues occur. The costs of upskilling, alongside additional expertise needed for training and contracting, where the level of skills required are more advanced, should also be considered (Ghobakhloo, 2018). Manufacturing industries are increasingly exploring predictive maintenance technologies for greater transparency in equipment performance (Chuang *et al.*, 2019). To remain competitive and at pace with digitisation, LDMSs should not put off investment, rather due diligence in research must be conducted to identify where this technology can facilitate continuous improvement within their operations (Martinez, 2019).

Cyber Physical Systems and Smart Factories

A network of sensor technologies can be installed in the factory environment to automate the tracking of inventory, transmitting live data to a system or software for analysis (Gilchrist, 2016, p.24; Chuang *et al.* 2019). Such technologies can be developed into a Cyber-Physical System (CPS), which comprises several communicative devices that connect the digital and physical elements of manufacturing operations (Ghobakhloo, 2018). Economic gains, via increased resource efficiency, and social benefits, relating to improved process flow for workers, are cited as prominent sustainable development outcomes of adopting I4.0 methodologies (Brozzi *et al.*, 2020), which could be enabled with a CPS. For example, digitally monitoring the lead time of product manufacture and the physical process flow, could highlight inefficiencies to target for improvement, allowing human resources to be constructively reallocated, and potentially reducing costs, creating better customer service.

Expertise is necessary to set-up the CPS as whilst the sensor devices can be programmed to perform autonomous functions, they are essentially unaware and only able to perform within the scope of the information installed in them (Wang *et al.*, 2016; Taha, Taha, and Thunberg, 2021, p. 133). This may be challenging for LDMSs due to limited human resources and costs of upskilling and training (Fachrunnisa *et al.*, 2020). Additionally, human knowledge and experience are required to verify recorded data, to ensure accurate interpretation and maintain the working link between the cyber and physical elements (Taha, Taha, and Thunberg, 2021, p. 133). This indicates that employee engagement is key to

successful transformation, and positive receptivity to change and upskilling are required to facilitate the process (Amaral and Peças, 2021).

Research suggests that CPS could be of great benefit to SMEs in managing production and logistics more efficiently but adoption in SMEs is still limited (Han and Trimi, 2022). Despite accessibility improvements, cost and lack of in-house digital expertise still present barriers to SMEs developing and maintaining CPS (Moeuf *et al.*, 2018; Han and Trimi, 2022), however investment in transformative technologies could be significantly beneficial to business growth (Moeuf *et al.*, 2018). To navigate the expense associated in developing a CPS, LDMSs could extend the functionality of existing machinery (Moeuf *et al.*, 2018), for example through integrating sensor devices. Identification of the most advantageous application of such technologies, can minimise implementation costs, as investments can be targeted to yield optimal benefits (Wang *et al.*, 2016; Moeuf *et al.*, 2018).

The CPS is a major element in establishing a Smart Factory (Ghobakhloo, 2018); the culmination of the various I4.0 methodologies implemented in the manufacturing environment, from the supply chain through to product delivery, underpinned by the business model and processes (Gilchrist, 2016, p. 217). Wang *et al.* (Wang *et al.*, 2016) discuss a smart factory framework; sensor devices collect data which is wirelessly collated, stored and processed as big data, and communicated to managers for analysis, decision-making, and planning. Vertical integration is a feature of the smart factory, facilitating the coordination of various departments throughout the company, to enable a streamlined and flexible organisational process (Wang *et al.*, 2016). Whilst incremental changes may seem more accessible for LDMSs, a holistic approach is required to fully take advantage of digital technologies, to enhance quality through product creation to delivery (Fachrunnisa *et al.*, 2020).

A smart factory system can provide benefits such as efficiency of processes, reduction of waste, and better customer service offering through ease of product customisation and reduced minimums (Wang *et al.*, 2016). The visibility and decentralising of information created through collated data, enables monitoring of productivity and performance, and operational adaptivity, alongside customer communication (Wang *et al.*, 2016). These benefits can be achieved throughout the business, from production processes to packaging and logistics (OECD, 2021, p. 19). However, limited skills and investment resources are commonly identified as barriers to SMEs implementing elements of digitisation (Moeuf *et al.*, 2018; Vukićević *et al.*, 2021). It is unsurprising then that physical inventory flow in many SMEs is still managed manually (Vukićević *et al.*, 2021), but interconnectivity is transforming the way businesses operate, and SMEs must develop digitisation in operations to remain competitive (Fachrunnisa *et al.*, 2020). If a fully integrated CPS or smart factory is unfeasible, targeting where digital technology can positively impact inefficiencies could facilitate progress (Moeuf *et al.*, 2018; Martinez, 2019). However, it is suggested that further research is needed to confirm the specific benefits the CPS, and resultant smart factories, can bring to SMEs (Han and Trimi, 2022). For LDMSs, developing a CPS and smart factory may not be feasible to pursue initially, but through strategic planning this may pose a significantly beneficial longer-term business goal, once digital development in infrastructure and skills are more mature.

Conclusions

Digitisation in LDMSs is key to building resilience and business longevity.

The rapid acceleration of digitisation in businesses globally, generated by the pandemic, has enabled increased resilience in responsive SMEs and has transformed the operational business landscape for the foreseeable future (Bianchini and Kwon, 2021, p.34). Therefore, digital technologies and skills in LDMSs are key development strategy factors for business sustainability to remain relevant. Adopting digitisation across the business helps to minimise silos, creating a holistic approach, achieved through data transparency and communication. For example, enhancing use of existing accessible technology, such as cloud computing, can enable big data collation and data mining. Enabling increased digital data is an achievable goal for LDMSs but research is required to determine the best route for the company context, reflecting limited resources and skills gaps. Onboarding key team members will help to target areas where digitisation will yield most benefit. This research demonstrates receptivity to digital developments and further upskilling the work force will be necessary for longer-term business resilience in LDMSs (Bianchini and Kwon, 2021, p.34).

How resilience is achieved.

I4.0 methodologies facilitate transparency, within the business and across supply chains, aiding business function alignment, supporting informed decision-making. Accessing live digital data enables rapid responses, and collation over time facilitates improved predictability. Digitisation in manufacturing functions enhances efficient resource management from inventory through to machine maintenance. Digital data technologies benefit functions such as market sensing, gaining greater customer knowledge for effective product development, and increased responsiveness to changing consumer demands. The culmination of these advantages is increased competitiveness, improved customer service, greater efficiency, and reduced waste - all indicators of business sustainability. Protecting cyber-security is of growing importance for expanding business digitisation, and greater awareness in LDMSs will help alleviate any associated fears, reducing respective barriers to digital implementation. Building this into the digital development strategy, alongside additional digital upskilling, will enable LDMSs to take advantage of current and future developments with greater confidence, whilst increasing practical business resilience also.

I4.0 creates opportunities for growth.

Innovative business models, adoption of technology, and the ability to realise sustainability goals are all suggested as key factors towards business growth (Galer, 2022). I4.0 methodologies can aid improvements across business functions to this end. In addition to cost and resource efficiencies, the capability to capture, analyse, and draw conclusions from digital data can facilitate improved product and process developments, enabling a more competitive service and market expansion. Increased transparency in the supply chain through data sharing can aid sustainability goals, by facilitating informed choices, enabling that transparency to be shared with the consumer. However, whilst environmental factors

can be improved on through Industry 4.0 adoption, it is suggested these may be supplementary rather than targeted (Brozzi *et al.*, 2020), for example contributing towards net zero through waste reduction and improved energy monitoring. Implementation of digital technologies both necessitates upskilling and facilitates opportunities, through time-saving and new job roles. As technology developments are ever-increasing, it would be beneficial for LDMSs to seek digital skills in new employees (Ghobakhloo, 2018) as company growth develops, continuing the progression towards increased digital capabilities.

Considerations for LDMSs.

In creating a strategy for process digitisation, incremental improvements which are paced within the capabilities and requirements of the organisation, may lead to greater success in sustainable development for LDMSs than opting for radical change (Martinez, 2019). However, investments should be made where diligent research indicates great benefits. Costs, return on investment, and lacking expertise are all indicated as barriers to adoption (Han and Trimi, 2022), but digitisation is key to keep pace with competitors, so management skills are required to assess where to invest to gain advantage at minimum cost. Employee engagement and receptivity to change are important factors in successful business transformations, so strong agile leadership is required to reverse ingrained attitudes and develop a holistic business strategy (Gilchrist, 2016, p.232).

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