SMAS
Scottish Manufacturing Advisory Service

Scottish Enterprise

Bringing Scottish Manufacturing to the 4.

4.0

Foreword by – Nick Shields Head of Business Support Services, Scottish Enterprise

Around the world, manufacturing businesses are rapidly transforming their operations with the adoption of digital technologies, fundamentally changing how products are made driving both productivity and competitive advantage.

Scotland has a thriving, innovative and diverse manufacturing sector. It is the country's productivity engine, responsible for over 50% of exports and 54% of R&D. As with many advanced economies, when it comes to investment in digital solutions, businesses are only beginning to scratch the surface of what is possible.

At the Scottish Manufacturing Advisory Service (SMAS) – our mission is to inspire and support Scottish manufacturers to maximise the opportunities presented by Industry 4.0. Since its launch in May 2018, the SMAS Industry 4.0 (i4.0) Review has raised awareness of i4.0 concepts, increased ambition with respect to investment in digital manufacturing and helped 180 businesses create their digital roadmap for the future.

This report sets out the findings from these reviews and draws out the significant opportunities identified by the businesses themselves that they can exploit to make the most of what i4.0 can offer. Importantly, these opportunities focus on people and skills as much as the variety of i4.0 technologies from automation to integration of systems and the effective use of data.

The data that informs the content of this report was gathered before the coronavirus outbreak. Since then, company engagement has highlighted examples of businesses being able to continue to operate with fewer challenges because of investments already made in i4.0.

While i4.0 is on the radar of many manufacturers and its benefits are well understood, for many the current focus is on business continuity. However, the case for investment in digital technologies is now a compelling one if businesses are to adapt and thrive.

In a previous period of economic disruption, Toyota's ability to adapt and thrive after the 1970's oil crisis gathered world-wide attention with the creation of its lean production system, which formed the basis for its enduring success. It became a focus of a study by MIT - 'The Machine that Changed the World' and the concept of 'Lean' thinking has gone on to transform the world of manufacturing. Industry commentators consider Industry 4.0 today's vehicle to transform production processes.

As manufacturers emerge from the COVID crisis, they too have an opportunity to re-imagine a business resilient future – and they don't need to do it alone. Support is pivotal in assisting companies to accelerate their rate of i4.0 adoption and Scotland's manufacturers are fortunate to have a connected ecosystem of organisations available to accelerate the rate of i4.0 adoption. This is available to all manufacturers regardless of size, sector, or i4.0 maturity.

With the establishment of the National Manufacturing Institute for Scotland (NMIS), Advancing Manufacturing Innovation Centres across Scotland, and SMAS's ongoing commitment to help businesses develop their digital roadmaps, there has never been a more opportune time for manufacturers to begin their i4.0 journey.

Executive Summary

This report summarises the outputs of 180 SMAS Industry 4.0 reviews undertaken by a cross section of manufacturing companies in Scotland over a two-year period. The Industry 4.0 review explored each company's current state versus desired future state against several criteria. The key output from the review was to align business strategy with technology adoption to create an effective, bespoke digital roadmap.

Ambition and a desire to invest in emerging technologies is high amongst the businesses supported with an i4.0 review. Over the next three years, three quarters are planning to have an i4.0 resource and training plan in place and 95% of companies wish to develop a formalised, data-driven process for gathering market data for the purposes of aligning product/service offering. Two thirds view connected devices as a low cost/low risk option for exploiting i4.0 benefits and 74% of roadmaps featured connected devices projects. And while 60% of companies have not moved beyond the investigation stage with respect to process automation and robotics, 70% state an ambition to implement and accrue benefit from these in order to create value.

The review identified seven key themes shown below, as areas for i4.0 implementation and these are explored in more detail in the main body of the report.
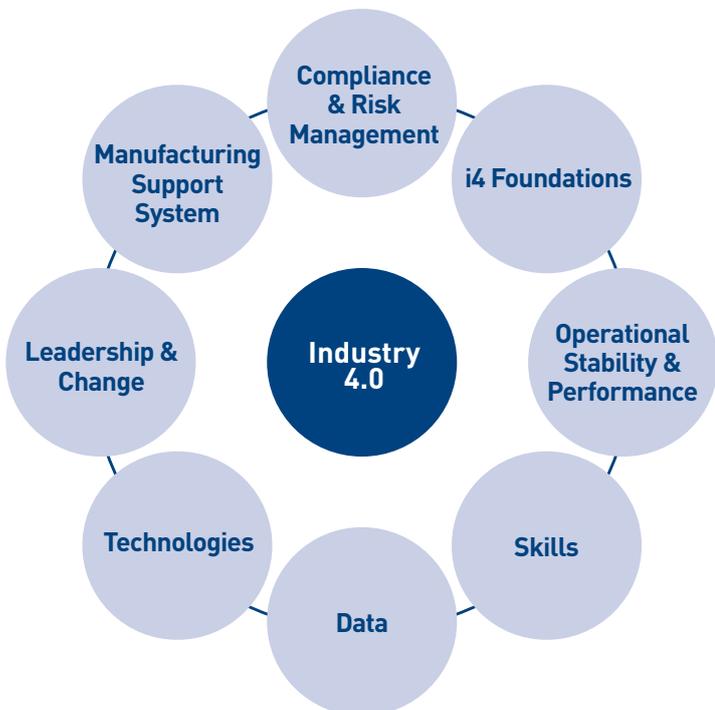
The findings demonstrate that while many firms have invested in specific areas of technology, they are yet to develop a longer term i4.0 strategy. It also highlights that operational excellence and visionary leadership are vital to support the investment and implementation of i4.0 technologies and skills.

Encouragingly, the findings further support the existence of integrated services and facilities available within the rapidly evolving support ecosystem in Scotland. These offer a high level of assistance that businesses need to successfully implement i4 technologies and will continue to be developed further.

Introduction

The 'Manufacturing Future for Scotland' action plan was published in February 2016 by the Scottish Government with the aim of stimulating ambition across the manufacturing landscape. It contains eight action plan themes: Leadership, Skills, Circular Economy, Energy Efficiency, Supply Chain Capability, Competitive Infrastructure, Technology & Innovation and Investment in SMART Manufacturing.

To support the 'SMART Manufacturing' theme, SMAS launched the Industry 4.0 Review in May 2018. The review is free to businesses, and since its launch, over 180 companies have participated in the review process.

The purpose of the i4.0 Review and the wider Manufacturing Action Plan 'Investment in SMART manufacturing' workstream is to support Scotland's ambition to raise productivity to world class levels. It is recognised widespread investment in capital assets, new technologies and digital manufacturing will be required, along with associated skills.

The i4.0 review process succeeded in building awareness and understanding of Industry 4.0 concepts and opportunities for companies. It also highlighted high levels of ambition & desire to invest in emerging technologies.

With the review successfully raising awareness and ambition, the analysis focused on identifying the support required to accelerate companies' digital manufacturing journey to take them from ambition to adoption.

1. Industry 4.0 Review Methodology

The i4.0 Review process is conducted over two separate days by a SMAS Practitioner and a Scottish Enterprise Digital Transformation Specialist. The structure of the review is as follows:

Introduction to Industry 4.0 – an introductory workshop takes client companies & leadership teams through i4.0 context, aims and ambitions. Initial data is gathered on company products, markets, strategic priorities, challenges and opportunities.

Diagnostic exercise – during the workshop, an assessment of the business is conducted against six constituent themes of an i4.0 maturity model. The objective is to agree on current state relating to i4.0 adoption and maturity, and the desired future state. The above two elements are carried out on Day One.

Industry 4.0 road-mapping session – a separate Day Two workshop is conducted to map out potential projects, initiatives and milestones that will enable the company to go from their current state to their desired future i4.0 state, as identified in the diagnostic session.

Reporting – the diagnostic results and roadmap initiatives are captured, summarised and presented back to the client company. Support and follow-up arrangements are discussed, and process ownership passes to the client company.

A comprehensive assessment of the business to identify strengths and opportunities is undertaken across six thematic areas to give an aligned approach towards i4.0:

Business Strategy - what are the ultimate goals of the business and what will catalyse growth?

Leadership & People – how can leadership, people and culture drive change and add value towards business growth?

Capital Assets – what current facilities, equipment and technology does the business currently have access to?

Technology Enablers – what technologies, platforms & tools are required/can be used to create value?

Data Management – how can data be harnessed to create meaningful information that can be intelligently used to drive the business forward?

Supply Chain & System Integration – what internal & external systems need to be linked up to connect: product, people, performance, plant & supply chain?

The i4.0 reviews were conducted either one to one on company premises, or at one to many workshops. The outputs have been compiled to give the following analysis and conclusions.

2. Key Findings

Current State Statistics
70% have yet to engage staff in i4 concepts
81% have yet to incorporate i4 into their strategy
84% have yet to create i4 resource or training plans
only **1%** see significant benefit from their current software
over **60%** cannot easily analyse or share data internally

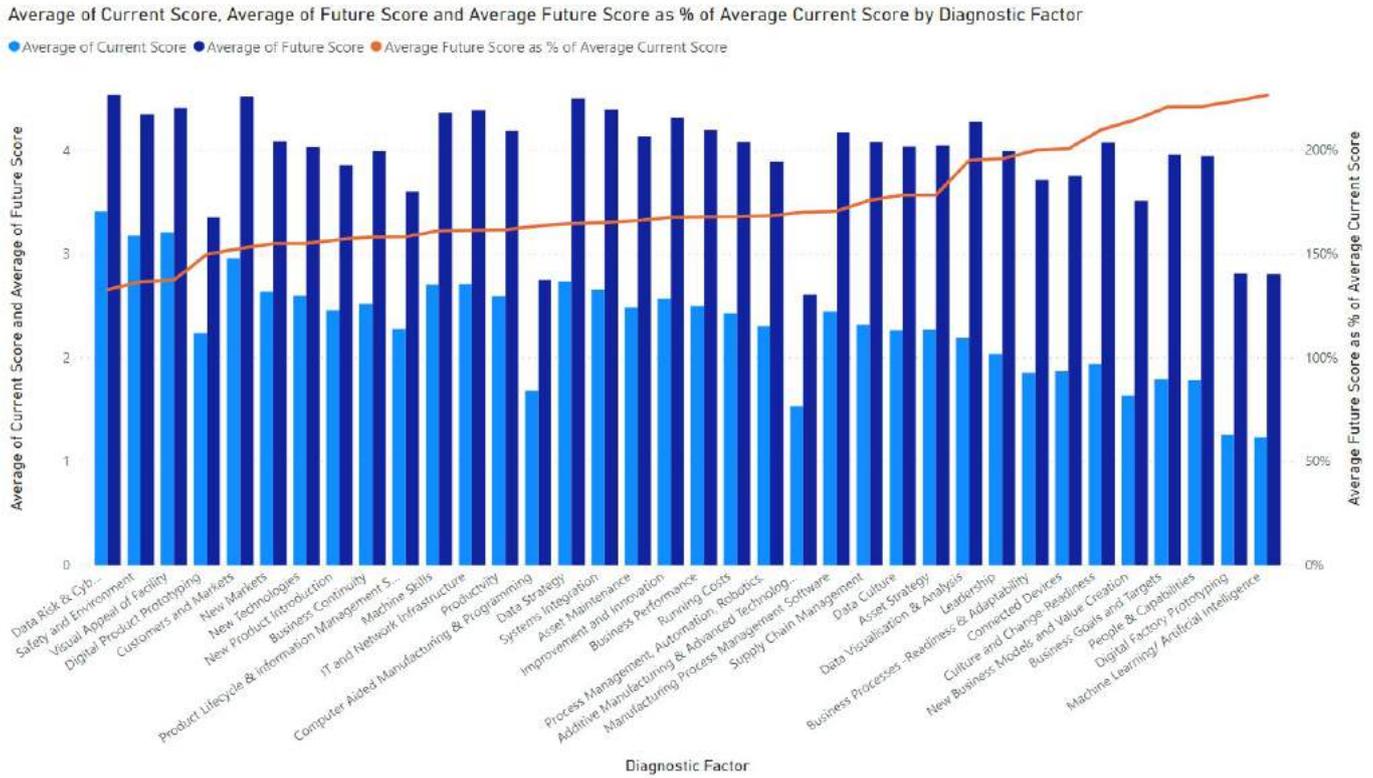| Future State Statistics |
|---|
| **80%** targeting staff that understand and embrace i4.0 |
| **80%** targeting i4.0 adoption and i4.0 enabled results |
| **77%** targeting formal, embedded i4.0 skills programmes |
| **85%** targeting demonstrable benefit from software systems |
| **80%** targeting effective processes to analyse and share data |

3. Summary of Findings

The information from the reviews has been consolidated to enable an overall picture to be generated and analysed. From this information and for summary purposes, the graph below (Figure 1) has been selected to offer an overall view from manufacturers of the current and future (3 year ambition) scoring of all 36 diagnostic questions across the six thematic areas.

Figure 1

Average of Current Score, Average of Future Score and Average Future Score as % of Average Current Score by Diagnostic Factor

● Average of Current Score ● Average of Future Score ● Average Future Score as % of Average Current Score

The key points and emerging themes are highlighted in (Figure 2, page 8) and explored further on the next page.

Figure 2

Average of **current score** ranked from **highest to lowest**, the **current score** in the **darker** colour. **Gap between** current and future score shown in **lighter** colour.
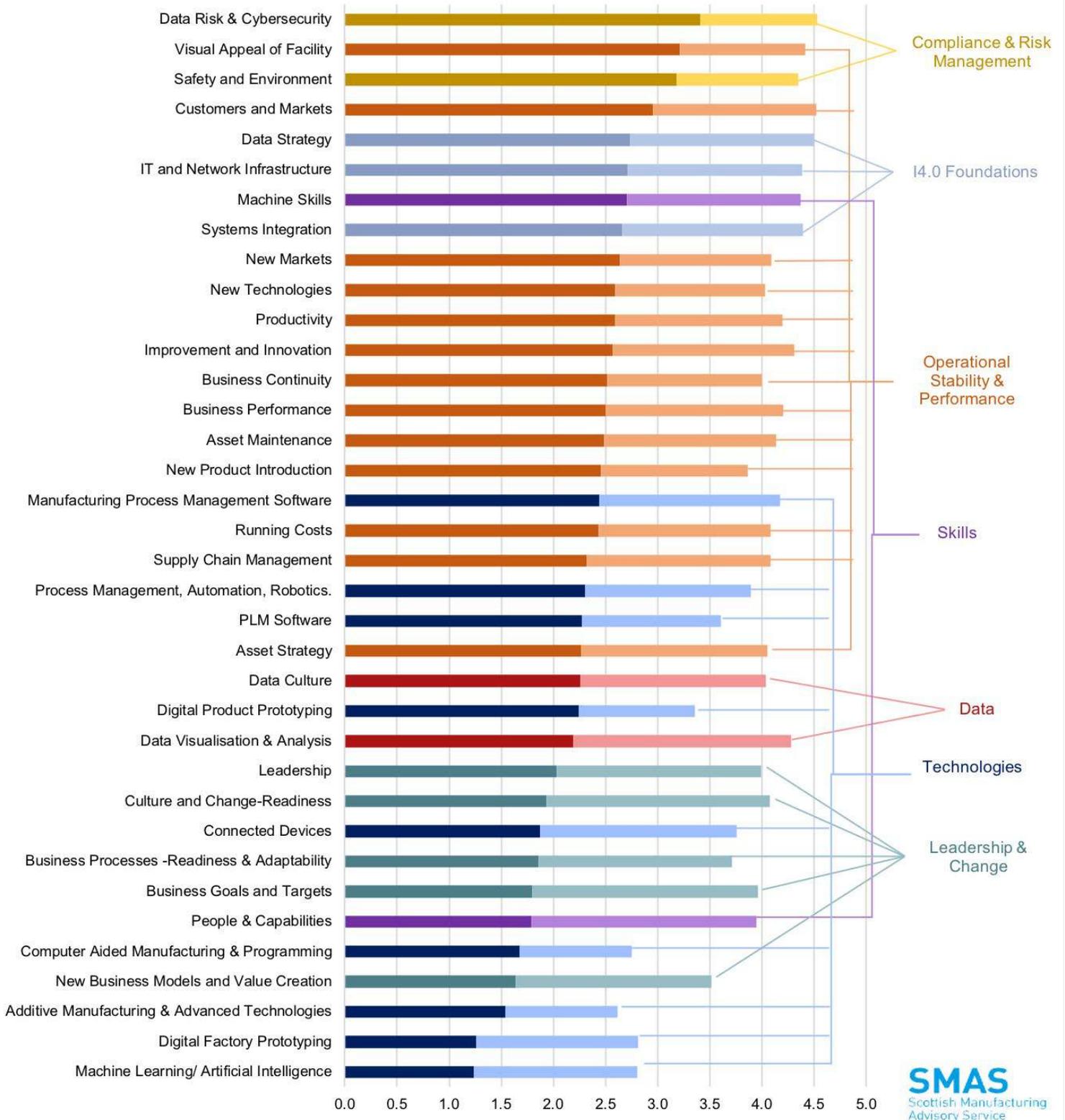
Compliance & Risk Management

Key Findings: Cybersecurity and Safety & Environment were the two themes with the highest scores. Businesses need to be proficient in these areas to manage business risk, continuity and reputation.

Support: Of those two themes, businesses were more likely to require advice on Cybersecurity and were signposted to schemes such as Cyber Essentials. This is a simple but effective Government backed scheme to help protect companies against the most common cyber attacks.

Industry 4.0 Foundations
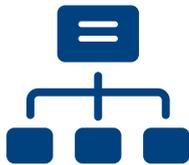
Key Findings: Data Strategy, Systems Integration, IT and Network Infrastructure are the core building blocks of strategy and technology to connect and start to deploy i4.0 technologies. Though businesses often have these in place, they seek to develop them further and better utilise data collection.

Support: The general support requirements for businesses were centred around two areas. The first was to gain more information/guidance to create or refine their Data Strategy. In these instances, companies were referred to organisations such as The Data Lab.

The second was companies' desire to increase their connectivity. Some indicated the need for more specific connectivity support e.g. increasing connectivity without compromising data security or improving the connectivity on their shop floor. Although these cases required specific support options, centres such as CENSIS are ideally positioned to provide this type of support.

Operational Stability & Performance

Key Findings: Companies require to continue to improve in areas such as Productivity, Introduction of New Products, Business Performance and Asset Strategy - all of which can be supported by SMAS and partner organisations. These are associated with the smooth running and progressive performance improvement of businesses.

In terms of Operational Stability & Performance, a range of scoring levels existed across the companies. Consistent low scoring led companies to acknowledge the need to strengthen

'operational foundations' before considering technology deployment. As an example, 88% of businesses stated that they had no established Asset Strategy – including no process around equipment lifecycle management.

Companies that already have an established improvement culture (Improvement and Innovation), are better positioned to make more rapid progress on their i4.0 journey.

To optimise investment in i4.0, companies need sound operational and organisational foundations in place. This will ensure companies unlock the full potential of any investment made and prevent the automation of waste.

Support: Where companies seek to continuously develop organisational & operational foundations. access to relevant support is readily available from SMAS, SE's Workplace Innovation and Digital Transformation team.

Skills

Key Findings: There are two themes related to the area of skills: Machine Skills and People & Capabilities.

Immediate skills needed to run businesses are apparent. However, planning towards future needs is more difficult. In terms of future / i4.0 skills, companies do not understand their requirements with 84% having yet to create i4.0 resource or training plans. This is an area where companies have expressed a large amount of ambition and focus. The ambition is evidenced in the diagnostic with 77% of companies targeting formal, embedded i4.0 skills programmes within three years and 93% have a project related to people and capabilities on their project roadmap.

Support: The SMAS i4.0 review has helped companies realise the need to develop a training and resource plan and prioritise i4.0 projects and in doing so the associated skills requirements.

Additionally, to further support companies assess their i4.0 skills requirements Skills Development Scotland (SDS) is leading a programme of work to create a Skills 4.0 diagnostic. This will enable companies to map and assess their current and future skills needs.

Data

Key Findings: Data Visualisation & Analysis and Data Culture were highlighted in the area of Data.

Data is identified as an area of frustration for businesses. Current systems and cultures mean that companies are not able to fully utilise data available to them. Findings showed that over 60% of companies were not able to easily analyse or share data internally.

Companies recognise that this is not simply a system issue. Culturally and behaviourally, there remains a reticence around the sharing of data, particularly in relation to cross-functional and company collaboration. This results in wasted effort within companies e.g. information held and analysed in local spreadsheets rather than shared systems. However, there is a great deal of ambition in this area as evidenced by 80% of companies targeting effective processes to analyse & share data.

Support: The i4.0 Review helped to contextualise the importance of data; how data can be used for performance and improvement purposes and the steps companies can take to progress in this area.

Some SME's requiring further support can consider the TORCH programme, delivered by The Data Lab.

Technologies

Key Findings: Themes most readily associated with i4 are: Manufacturing Process Management Software, Connected Devices, Process Management, Automation, Robotics, Digital Factory Prototyping, Digital Product Prototyping, Computer Aided Manufacturing & Programming, Product Lifecycle & information Management Software, Additive Manufacturing & Advanced Technologies, and Machine Learning/Artificial Intelligence
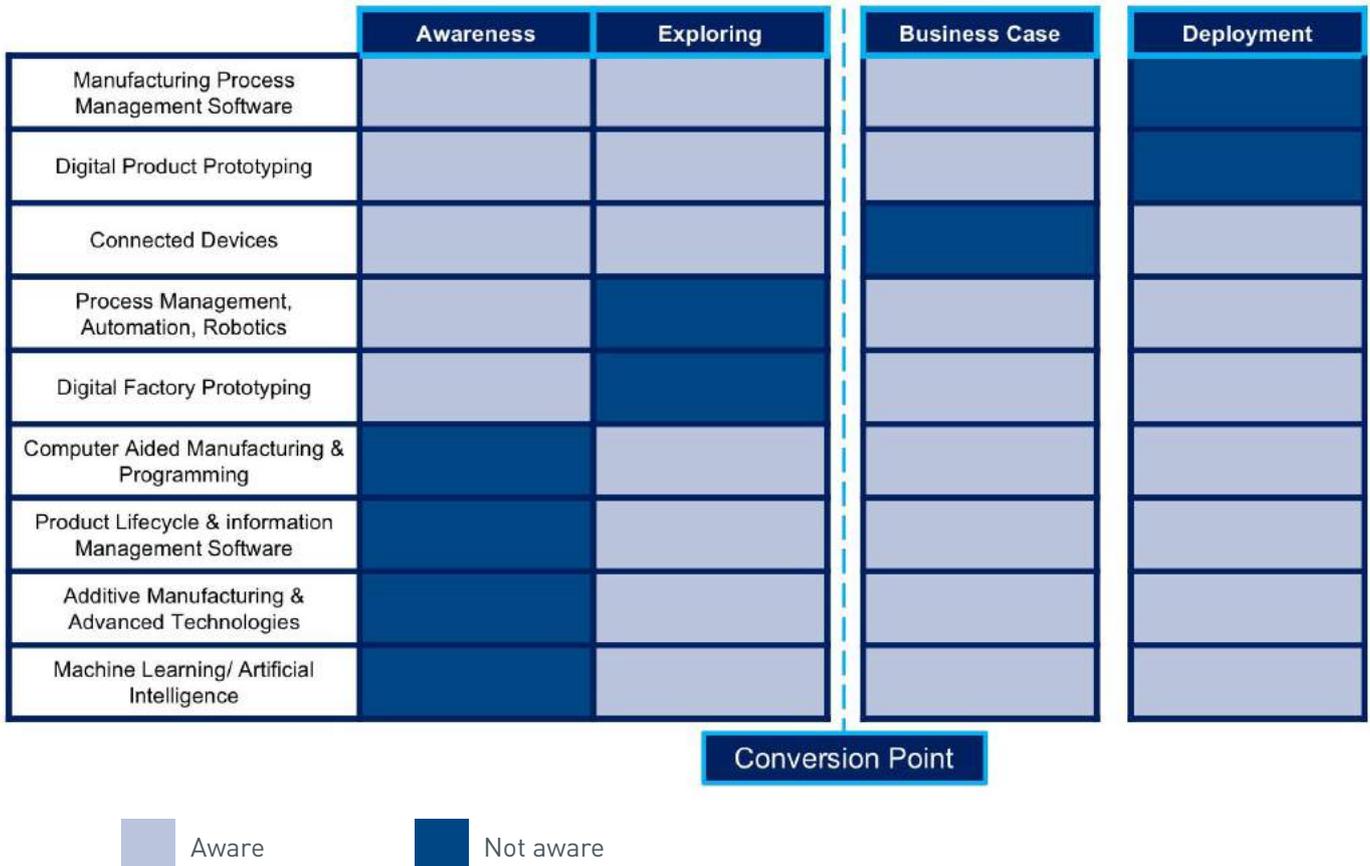
The review was designed to create awareness and understanding of i4.0 concepts & opportunities for companies. It also gives companies an overview of enabling technologies to consider as part of any investment & deployment programme.

The status of companies regarding adoption of i4.0 technologies can be categorised in one of four ways:

- **Awareness** - Companies have an awareness of the technology but are struggling to relate any potential benefits to it and there is a lack of interest to explore it further.

- **Exploring** - Companies have an awareness of the technology and understand that it would be of benefit but feel that the potential barriers (risk, costs, etc.) would be too large. They are exploring further but need to be convinced that the technology is appropriate for them.

- **Business Case** – Companies are convinced that the technology is appropriate for them. They are looking at specific items and creating a business case to confirm the costs and define the expected benefits.

- **Deployment** – Where companies have already deployed technology there was a common theme of ongoing efforts to optimise the benefits.

Using these categories, the matrix below (Figure:3) has been created to show the general view companies have towards the technologies which would be appropriate for them:

Figure 3

	Awareness	Exploring	Business Case	Deployment
Manufacturing Process Management Software	Aware	Aware	Aware	Not aware
Digital Product Prototyping	Aware	Aware	Aware	Not aware
Connected Devices	Aware	Aware	Not aware	Aware
Process Management, Automation, Robotics	Aware	Not aware	Aware	Aware
Digital Factory Prototyping	Aware	Not aware	Aware	Aware
Computer Aided Manufacturing & Programming	Not aware	Aware	Aware	Aware
Product Lifecycle & information Management Software	Not aware	Aware	Aware	Aware
Additive Manufacturing & Advanced Technologies	Not aware	Aware	Aware	Aware
Machine Learning/ Artificial Intelligence	Not aware	Aware	Aware	Aware

Conversion Point

■ Aware   ■ Not aware

Support: For companies at **Deployment** phase, the focus is often on post deployment optimisation. As an example, only 1% see significant benefit from current business software with 85% targeting demonstrable improvements and benefits.

For technologies at the **Awareness** stage, the support most appropriate are those that enable the companies to better understand the technology and associated benefits and can include:

Best Practice Visits – peer to peer networking to view and understand technologies in action. This will be discussed further under Leadership and Change. SMAS facilitates best practice visits as do partner organisations and technology suppliers.

Physical Examples/Demonstrators – technology demonstrator cells are available at Innovate UK'S High Value Manufacturing Catapults, Scottish Funding Council Innovation Centres and will be a key feature of Scottish Governments flagship National Manufacturing Institute for Scotland and the Scottish Advancing Manufacturing Innovation Hubs. An overview of these centres is detailed in the support ecosystem section.

Case Study Library – detailed case studies of technology deployment by companies from the same sector and size give a detailed understanding of the benefits. It also creates a sense of urgency by seeing potential competitors benefit from technology use. Examples of these libraries can be found on the websites of the Scottish Funding Council Innovation Centres.

For technologies at the **Exploring** stage companies have an awareness of the technology and the potential benefits. The most impactful support will therefore be addressing the barriers both real and perceived to deploying the technology. This may involve dispelling any misunderstandings that companies have about technology.

- **Expert Process Review** – A review of the current manufacturing processes by subject matter experts to identify specific processes that would benefit from the deployment of the technology. Such reviews can also identify the approximate costs. For example, the Advanced Forming Research Centres Automation review, which is free for manufacturing SMEs.

- **Technology Training** – As detailed in the skills sections, access to the correct skills is viewed as critical by companies. Support to identify and deliver training in the technical skills to operate the technology is essential. Support can be sourced from equipment suppliers, colleges, universities and is evolving through some AMCFs. This training should be differentiated from CPD style training that will be covered under Leadership and Change.

- **Pilot Projects** – Given the potential scale and cost of technology deployment, companies will need to be supported through smaller scale demonstrator/proof of concept projects. This will typically involve lower cost versions of the final technology solution that can be deployed for a short period of time to prove the benefits. Support is available via Innovate UK High Value Manufacturing Catapults to support the de-risking of investment and innovation. This will also be a key service of NMIS.

- **Collaborative Projects** – Support to facilitate the creation of collaborative projects to develop or deploy the same technology in two or more companies. This approach means that both companies achieve the benefits associated with deploying the technology but spread the costs and so reduce the risks.

By successfully supporting companies through the exploration phase, they will reach a **Conversion Point**. At this stage, they will understand the benefits of the technology and believe they can deploy the technology.

In the **Business Case** stage, companies need impartial support to evaluate the technology to understand not if they can deploy the technology, but whether they should. This support can be characterised as an 'honest broker' or 'critical friend' that will guide the company through evaluating the justification process.

Companies require support at one or any of the four elements to translate an 'articulation of need' into 'technology requirements' and then review the feasibility of the solution.

- **Technology Specification** - Translation of the identified technology opportunity to a defined technology requirement – for a solution that is fit for purpose and not over specified

- **Return on Investment** – Carry out a cost benefit analysis and understand if the proposed solution has a return on investment (ROI) that makes economic sense

- **Partner identification** – Help the company identify technology suppliers that fulfil their needs and are a good fit for the company's needs & situation e.g. system integrators

- **Implementation planning** – Use their knowledge and experience to outline a roll-out plan for the technologies to avoid common pitfalls and increase the chance of success.

A recommendation of the report is to identify accessible funding for companies researching, testing and deploying technology.

The Support Ecosystem section gives an overview of some of the organisations that deliver the support outlined above. Regardless of where businesses sit in the deployment of technologies, there is a wealth of connected support available to them in Scotland.

Leadership and Change

Key Findings: The importance of leadership cannot be overstated for companies as a key enabler at the start of their i4.0 journey. Leadership support for the change processes is required to create vision and ambition. The themes associated with Leadership and Change are: Leadership, Culture and Change-Readiness, Business Processes -Readiness & Adaptability, Business Goals and Targets and New Business Models and Value Creation.

Companies recognise the importance of these themes and acknowledge the scale of work required but have ambition to progress. This is evidenced by 70% of company leaders having yet to engage staff in i4.0 but 80% targeting a culture that understands and embraces i4.0 within 3 years.

This is further evidenced by 81% of companies yet to incorporate i4.0 into their strategy and 80% targeting i4.0 adoption and results within three years. The review enabled leadership teams to gain confidence in and knowledge of i4.0 and take teams through a prioritisation exercise to develop a roadmap. It also brought company leadership together, enabled valuable conversation and started the process of creating a shared vision for the future.

Support: Leadership teams require support to further develop an i4.0 strategy to drive business resilience and competitiveness, while engaging with the workforce to build i4.0 mindsets, skills and behaviours to support modern efficient companies.

Learning Journeys – Seeing technology in action and in context helps the engagement with and understanding of the potential benefits. Scottish Enterprise & SMAS provide Learning Journey visits to companies willing to share areas of best practice and their journey towards investment and deployment. Learning journeys take the form of individual and multi-site visits with examples in Scotland, UK and Europe.

Note: Covid-19 Restrictions to travel and visits currently exist and webinars are an evolving alternative.

Business Improvement Academy (BIA) – SMAS has delivered BIA's for several years to support businesses that recognise the need to lead change and effective engagement to provide sustainable continuous improvement in order to become more productive. BIA's are a modular programme for peer to

peer cohorts. The programme combines the use of traditional lean problem-solving methodology with an introduction to soft skills learning around Change, Behaviour & Effective Leadership. There is an adaptation to this programme which includes exposure to i4.0 learning. The course is a mix of workshop based active learning combined with best practice visits and on-site (one-to-one) practical project support.

i4.0 Leadership Network – A network consisting of leaders from companies embarking on or thinking of embarking on a I4.0 change journey. By discussing the topic with peers, sharing challenges/opportunities and progress this group crystallise each other's thinking so creating a clearer vision which they are better able to articulate.
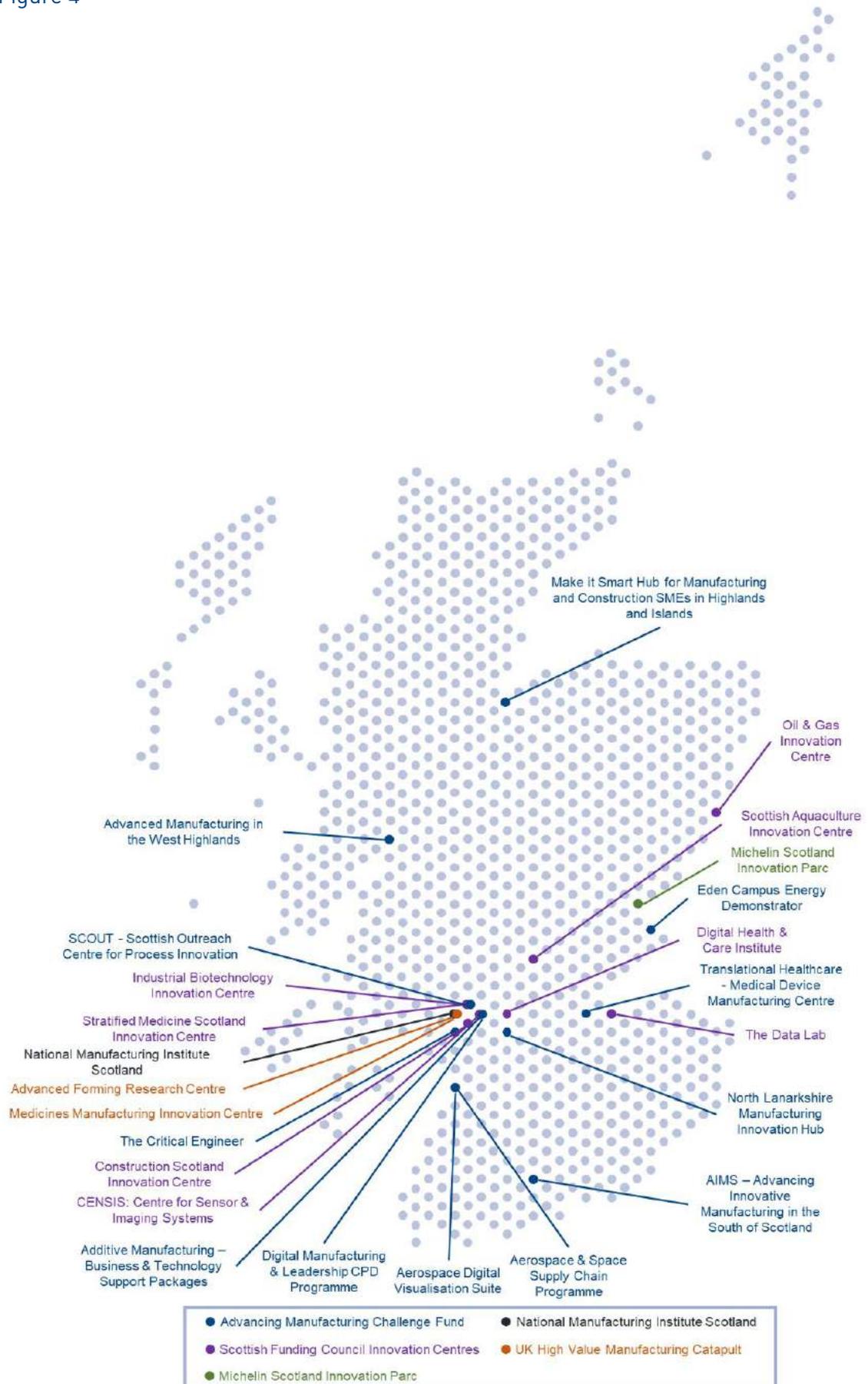
4. Support Ecosystem

To support the competitiveness and innovation with Scottish Manufacturing a significant investment of c.£200m has been committed to create a world class manufacturing innovation system inclusive of National Manufacturing Institute Scotland, Advanced Manufacturing Innovation District and Advancing Manufacturing Challenge Fund projects. The evolving support ecosystem will support the acceleration of i4.0 journeys and development. Access to advice and support to de-risk investment and innovation will be accessible to the Scottish manufacturing community.

Companies that have identified a project, technology or challenge need not be alone and utilising this network of support is intended to accelerate company productivity.

The picture on the next page (Figure 4, page 17) highlights some of the manufacturing support ecosystem now in place.

Figure 4

Make it Smart Hub for Manufacturing and Construction SMEs in Highlands and Islands

Oil & Gas Innovation Centre

Scottish Aquaculture Innovation Centre

Michelin Scotland Innovation Parc

Eden Campus Energy Demonstrator

Advanced Manufacturing in the West Highlands

SCOUT - Scottish Outreach Centre for Process Innovation

Industrial Biotechnology Innovation Centre

Stratified Medicine Scotland Innovation Centre

National Manufacturing Institute Scotland

Advanced Forming Research Centre

Medicines Manufacturing Innovation Centre

The Critical Engineer

Construction Scotland Innovation Centre

CENSIS: Centre for Sensor & Imaging Systems

Additive Manufacturing – Business & Technology Support Packages

Digital Manufacturing & Leadership CPD Programme

Aerospace Digital Visualisation Suite

Aerospace & Space Supply Chain Programme

Digital Health & Care Institute

Translational Healthcare - Medical Device Manufacturing Centre

The Data Lab

North Lanarkshire Manufacturing Innovation Hub

AIMS – Advancing Innovative Manufacturing in the South of Scotland

- Advancing Manufacturing Challenge Fund
- Scottish Funding Council Innovation Centres
- Michelin Scotland Innovation Parc
- National Manufacturing Institute Scotland
- UK High Value Manufacturing Catapult

5. Success Stories

The following are examples of Scottish companies that have invested in different technologies and achieved success:
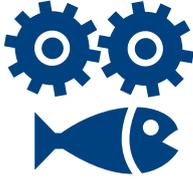
Subsea equipment manufacturer introduced an analytics tool, originally developed to analyse data from the New York Stock Exchange. As soon as production information was fed into the system it identified a correlation between factors which had never been previously understood, leading to a significant increase in yield.

SME food company invested in Shop Floor Data Collection (SFDC), achieving the expected benefits of greater control of costs and better decision making, but also the unexpected benefits of more focused training and improved employee appraisals. They can now understand and compare operator, line and even job performance against an average time. This allows for operator development and they can understand if they take more time to set-up or doing a specific task/job and they can be trained. This data and knowledge also feed into the appraisal process making it more robust and data led.

Industrial fan OEM integrated sensor and communication systems into their products and used this to create an online platform with performance dashboards. This enabled predictive maintenance leading to significant savings. Feedback and data can be used in the development of new products. Originally an internal development, the system (or similar) is now in customer specifications, leading to greater sales.

Marine engineering firm switched to using laser scanning when conducting a survey of the ship ahead of their projects to retrofit components. The use of this technology was quicker and more accurate than traditional processes. The quicker survey meant the clients ship could spend less time docked up. The accurate survey lead to more accurate fabricated parts, which fitted first time, increasing the speed and quality of the retrofitting process.

Small manufacturer automated the delivery of material to a CNC machine using a cobot. This enabled them to run lights out at the machine which had previously been their bottleneck. They used the same make of Cobot as their CNC machine which as well as simplifying the deployment meant they were able to strike a deal. In exchange for acting as a show case site the CNC maker gave them support and advice in the deployment.

Small family jewellery business used Computer Aided Design (CAD) and 3D printing processes to create moulds and patterns for the centuries old lost wax moulding process. This allowed them to create jewellery with complex geometric forms which were a hit with their customers. It also enabled them to take on individual commissions as the technology decreased the time and cost involved in such projects.

6. Key Contacts & Links

To request a SMAS Industry 4.0 Review, for more information on the current leadership programme or for more information on this report Contact:

https://www.scottish-enterprise.com/support-for-businesses/develop-products-and-services/support-for-manufacturers/support-for-manufacturers-enquiry

Support ecosystem

National Manufacturing Institute Scotland (NMIS): https://www.nmis.scot/get-in-touch/

Advancing Manufacturing Challenge Fund (AMCF) - Full details on the projects and their contact details are here: https://www.scottish-enterprise.com/support-for-businesses/develop-products-and-services/innovation-support/advancing-manufacturing-challenge-fund

Innovation Centres

Full details on the centres and their contact details are here:
https://www.innovationcentres.scot/get-in-touch/

Support ecosystem:
Cyber Security Support
CENSIS
The Data Lab
SE Workplace Innovation
SDS Skills 4.0
High Value Manufacturing Catapults
Scottish Funding Council Innovation Centres
AFRC Automation Review