INTERACT

Future of Digital Manufacturing Ecosystems

2040 Scenarios

October 2023

MAKE uk
The Manufacturers' Organisation

MADE SMARTER

INTERACT
Pioneering human insight for industry

UKRI Economic and Social Research Council

MIDLANDS ENGINE

Foreword

See the shape of digital manufacturing today

Disruption, digital innovation, new business models… the world of manufacturing is changing rapidly, perhaps faster than ever before. To adapt and survive, businesses must anticipate changes, identify opportunities and make informed decisions.

So, how can you be ready for the changes that lie ahead? How can you pivot to be equally productive and sustainable, delivering progress with purpose?

The InterAct Future of Digital Manufacturing Ecosystems research team has put together a vital report that brings you the information you need, at your fingertips, outlining potential future scenarios and the associated opportunities for the manufacturing world.

Future of Digital Marketing Ecosystems – 2040 Scenarios

These scenarios map out four potential alternatives for the digital manufacturers of tomorrow:

- **Productivity Powerhouse**
- **Flexibility as Standard**
- **Sustainability Champion**
- **Happy and Sustainable Workforce**

Some inspiring and welcome findings

Read on to find out more about how the most useful measure of sustainable progress is total factor productivity, which accounts for inputs beyond labour – such as materials, energy and administrative time – to compare them against total outputs. You will also learn how these inputs can be measured against one another, and how businesses can begin working towards achieving them.

As the report shows, by considering the human factors behind digitalisation today, you'll be much better placed to build true resilience into your business tomorrow.

The report leads to some inspiring conclusions. For instance, industrial digitalisation looks set not to harm jobs in the sector, but the opposite – with a net increase in manufacturing jobs. Industrial Digital Technologies (IDTs) are also predicted to create a more resource-efficient, sustainable and resilient economy.

In a world where every part of the value chain will start considering and delivering a more sustainable and inclusive future, this report provides inspiration and suggested road maps to help businesses like yours take the necessary next steps.

About Made Smarter Innovation

The report was created by a research team at Loughborough Business School and is a key output of the InterAct Network, part of the Made Smarter Innovation Challenge.

Made Smarter aims to transform business by focusing on three key objectives:

- Creating a connected collaborative ecosystem, where the best ideas can have the momentum to become industrial scale solutions
- Putting people at the heart of digitalisation, harnessing diversity, connecting communities and creating compelling solutions
- Delivering the digital manufacturing future we want, where we make things better, not just products but also society and the environment

The initiative aims to boost productivity by 30%, introducing £2.3 billion of Gross Value Added as well as up to 4,000 jobs, and reducing carbon dioxide by 4.5% and waste by 25%. The aims are ambitious, but achievable, as the **Future of Digital Manufacturing Ecosystems – 2040 Scenarios** makes clear.

- Ben Farmer, Deputy Director for the Made Smarter Innovation Challenge

Content

Research Programme

InterAct (Ref: ES/W007231/1) is funded by **UKRI** as an investment under the **Made Smarter Innovation (MSI)** challenge. InterAct seeks to "pioneer human insight for industry" and is a call to arms for academics from the social sciences to support the innovation and diffusion of digital technologies that will result in a stronger, more resilient UK manufacturing industry. Working alongside other partners within the wider Made Smarter community, the long-term vision is to build a strong, vibrant, interdisciplinary community to support the digitalisation of UK manufacturing.

The InterAct team is taking a multi-stakeholder approach to understanding industrial challenges that UK manufacturing is facing and developing practical solutions through collaborations and knowledge transfer. As a part of InterAct's core research programme, the **Future of Digital Manufacturing Ecosystems** project aims to identify the 2040 Scenarios for UK manufacturing and develop digital roadmaps to support the overall transformation.

We hope you find this report insightful and welcome any questions and feedback you may have. You can reach the team at info@interact-hub.org

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Recommended citation

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Executive Summary

Our purpose

As part of the **Future of Digital Manufacturing Ecosystems** project, this report presents the critical insights generated by both primary (literature review) and secondary (expert interview, focus group) research on the possible scenarios and future visions for UK manufacturing by 2040. The purpose of this **'2040 Scenarios'** report is to showcase the identified future visions and snapshots for the industry, helping manufacturing practitioners, policymakers, and academics to envision future prospects and develop practical and measurable action plans to support the overall transformation.

In response to the industrial challenges in productivity, sustainability, resilience and the well-being of the workforce, the work focuses on visualising the future of the UK manufacturing ecosystems in those key domains. It aims to provide a better understanding of the future visions of the industry, potential new business models and the role of industrial digital technologies (IDTs) in enabling the vision. The scenario work can be used as a reference guide for strategic planning and should provide useful inputs into policymaking and business decision-making.

Core themes...

The report includes some core themes that serve as the main building blocks for the scenario work, and the definitions are provided below to establish a common understanding before a deep dive into the detailed scenario.

End-to-end supply chain (E2E SC) – An integrated system that links together multiple firms to turn raw materials into finished products that can be delivered to end customers.

Manufacturing ecosystems – Being a part of the ecosystem enables firms to establish 'many-to-many' relationships with others by taking part in multiple global supply chains. The key benefit is that firms can leverage each other's operational assets and capabilities to co-create value and achieve mutual benefits.

Industrial digital technology (IDT) – Refers to Industry 4.0 technologies, such as Artificial Intelligence, Digital Twin, Smart Analytics, and Blockchain, that enable the improvement of end-to-end supply chain visibility, traceability, and connectivity.

Productivity – Building on the economic definition of productivity - 'growth value added per employee', the term in this report focuses on the operational efficiency (i.e. time, cost and quality) in the manufacturing industry.

Sustainability – Links to United Nation's Sustainability Goal (UNSG) 12 Responsible Consumption and Production, which focuses on improving the overall material and energy efficiency throughout E2E SCs.

Resilience – Focuses on improving overall supply chain flexibility through integrated planning (dynamic flexibility) and network reconfiguration (structural flexibility)

Wellbeing – Focuses on the human element in the manufacturing industry, particularly exploring solutions to address issues around talent development and operating models

Four scenarios

Four scenarios were identified to provide a holistic view of the preferred future state for the industry, each containing sub-elements (a set of visions and snapshots) to bring the abstract ideas to life.

Introduction

Challenges Facing the UK Manufacturing Industry...

UK manufacturing has faced tremendous challenges in the past decades due to external global disruptions and internal operational inefficiency. Lessons learned from Brexit and COVID-19 highlight the importance of supply chains (SCs), which act as a critical means of matching the demand with appropriate supply. Since the UK is a net importer (buys more from other countries than it sells to), the country has struggled to make positive progress towards its productivity (to make things at the lowest possible cost), sustainability (to move towards NetZero) and resilience (to maintain operations continuity during disruptions) goals[1].

Although the industry has recognised that nowadays 'it's supply chains that compete, not individual firms'[2], the traditional 'silo thinking' mindset (focusing on improving the efficiency of individual business function/entity rather than the end-to-end SC) has largely stalled the opportunity to achieve overall growth. This creates an ever-growing gap between large and small firms, which provides the former with the advantage to grow faster at the expense of the latter (usually SMEs who supply to large firms)[3]. To make a U-turn in response to the enduring challenges, firms must take a more coordinated approach to identify the mutual goals and manage their SCs accordingly to produce benefits for everyone.

However, this is difficult to achieve due to poor integration and visibility across the end-to-end SC. In reality, firms interact only with their tier-1 suppliers which largely constrains their access to the entire SC network.

This limits their ability to sense and seize new business opportunities in a broad context by leveraging one another's knowledge and capabilities. Therefore, taking the ecosystem approach in managing its SC network enables firms to build 'many-to-many' relationships with different firms with a set of different operational capabilities and assets. By exploring collaboration opportunities in the network, firms could work closely with each other towards mutual goals – to be more productive, sustainable, and resilient through knowledge transfer and asset sharing.

Industrial digital technologies (IDTs) are critical to creating the future we want...[4]

Through the industrial revolution, we observed how Industry 4.0 technologies could affect our lives in different aspects. Adopting digital solutions offers better visibility (uncovers SC issues in a timely manner), connectivity (smooth communications between SC partners at different levels), analytics (enables better decision-making based on data insights) and traceability (track and trace material flow and other factors such as carbon emissions from the end-to-end SC). Some large global corporates have started benefiting from adopting IDTs in their operations, but this only created limited impacts as their upstream suppliers (mostly Small and Medium Enterprises (SMEs)) are still in the early stage of IDT adoption.

Without scaling the IDT application across end-to-end SCs and beyond, firms are struggling to achieve improved productivity and sustainability. As 'Rome was not built in a day'; the same logic applies, this requires a system thinking to understand the future of the manufacturing ecosystem and consider what actions can be taken to leverage the power of IDTs in delivering the future we want.

Future of Digital Manufacturing Ecosystems – 2040 Scenarios

Whilst it is impossible to predict the future, envisioning it enables us to explore different future scenarios and identify a common future vision by answering the following questions. With a clearly defined vision, we could then work backwards to identify critical milestones and steps towards the ideal future state.

- What could the future of the digital UK manufacturing ecosystem look like?
- What are associated business models?
- What role does IDT play in enabling the vision?

This report presents the key findings of the scenario development, which focuses on identifying the ideal future state for the UK manufacturing industry in 2040. In total, four scenarios, 12 visions and 33 snapshots were developed to provide comprehensive views to answering the above questions.

Approach

Our approach...

The scenario development consists of five key stages[5,6]:

STAGE 1
Gathering insights on the key topics (preferred future for UK manufacturing, potential business model, the role of IDTs & relevant enablers/ inhibitors) through a series of 1:1 expert interviews and group discussions through the Discover Day. A multi-stakeholder approach was adopted to capture ideas from industrialists, policymakers and academics.

STAGE 2
Analysing individual interview/focus group data to establish a basic understanding of emerging themes, and capture common and different arguments between stakeholders.

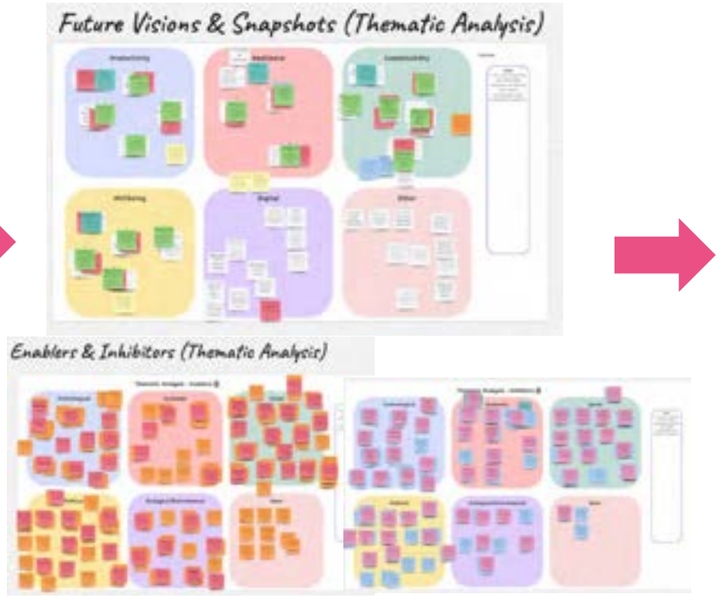
STAGE 3
Conducting thematic analysis to cluster findings under core themes; the future visions were analysed through five lenses (i.e., productivity, resilience, sustainability, wellbeing and digitalisation) and enablers/inhibitors were captured from the aspects of technological, economic, social, political (legal) and environmental.

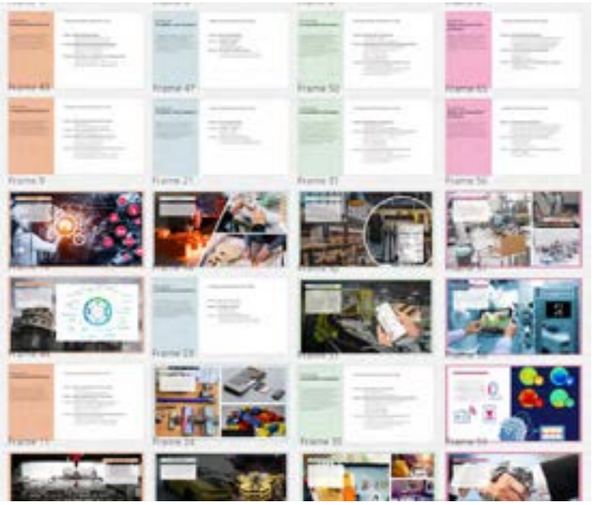
STAGE 4
Generating an initial version of scenarios, visions and snapshots for internal discussions with InterAct colleagues and Made Smarter Innovation team.

STAGE 5
Revising the scenario work to address feedback received from the previous stage.

22 expert interviews

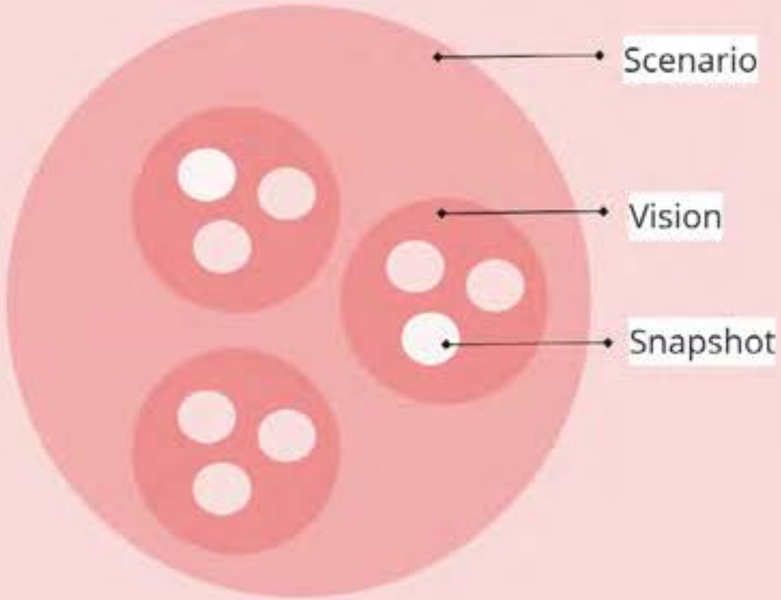
2 focus groups





SCENARIO 2040

Approach



- A **scenario** describes a preferred future situation[5]
- A **vision** can be exemplified with a set of snapshots from the future, and multiple visions may be used to articulate a scenario
- A **snapshot** from the future is the most specific component of a vision and can provide 'depth' and 'substance' to it

1

Productivity Powerhouse

2

Flexibility as the Standard

3

Sustainability Champion

4

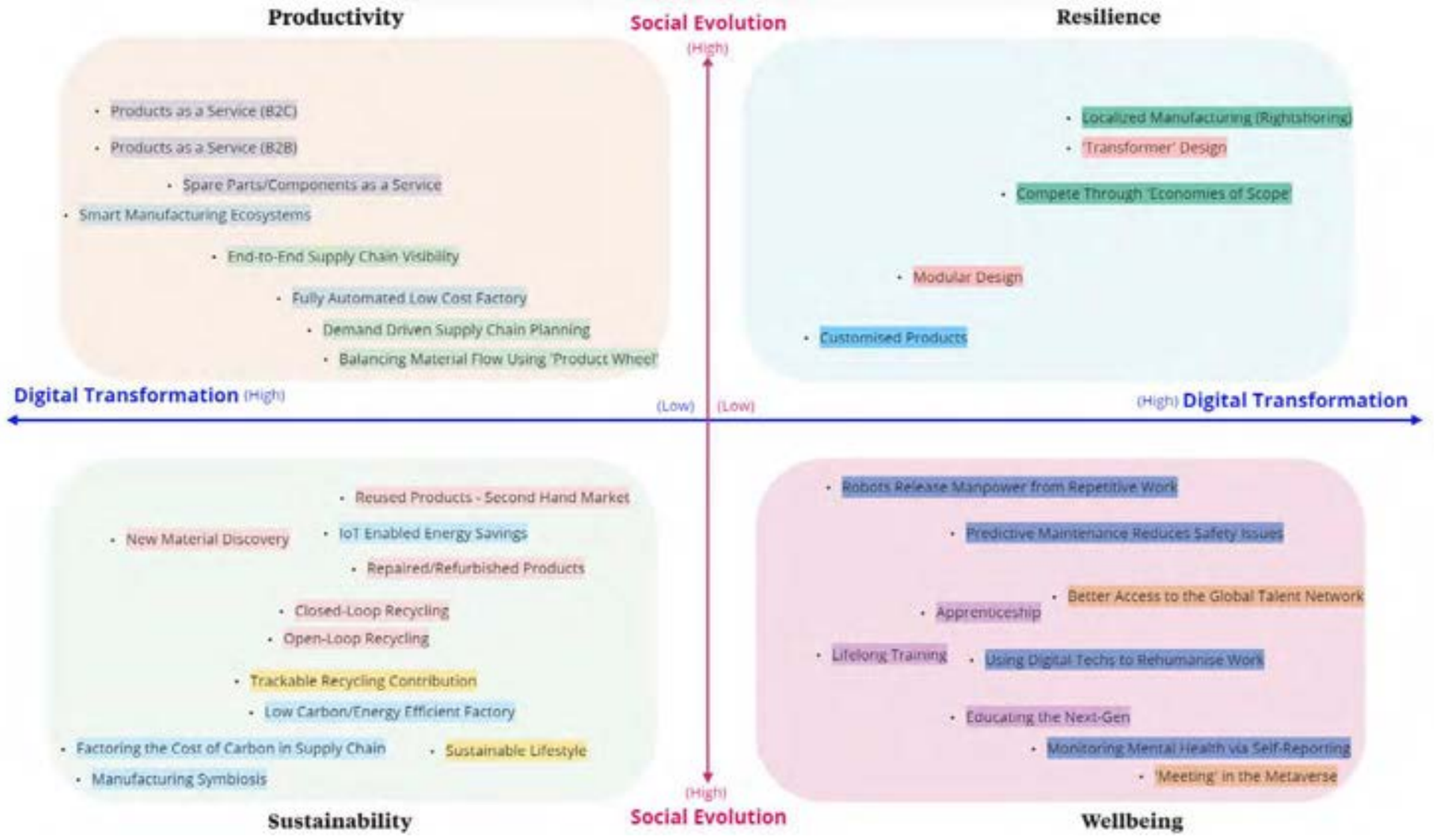
Happy & Sustainable Workforce

Four scenarios and two critical drivers…

Under the four scenarios, a total of 12 visions and 33 snapshots were generated to provide a holistic view of what the future could look like for UK manufacturing. Findings also show that there are two common factors that drive the changes across different domains.

- **Digital transformation (X-axis)** indicates the level of digitalisation that firms need to achieve to realise each snapshot (deliver the change)
- **Social evolution (Y-axis)** refers to the level of social changes in the broad community, such as changes in individual behaviour or mindset that transform the cultural and social institutions

Mapping snapshots against the two dimensions helps to understand the potential connections between them as well as the pathways to achieve the visions.



Scenario Vision Snapshot

- Digital Manufacturing
- Digitally Enabled Integrated Offerings
- Smart End-to-End Supply Chain Management
- Mass Customisation
- 'Flexible' Products
- Distributed Manufacturing
- Responsible Consumption
- Mining Resources from the Current Ecosystems
- Carbon-Zero Manufacturing Ecosystems
- Better Health & Wellbeing
- Sustainable Talent Development
- Workforce is a Part of the Digital Ecosystem

‘A sum is greater than its parts’
It requires a system thinking approach…

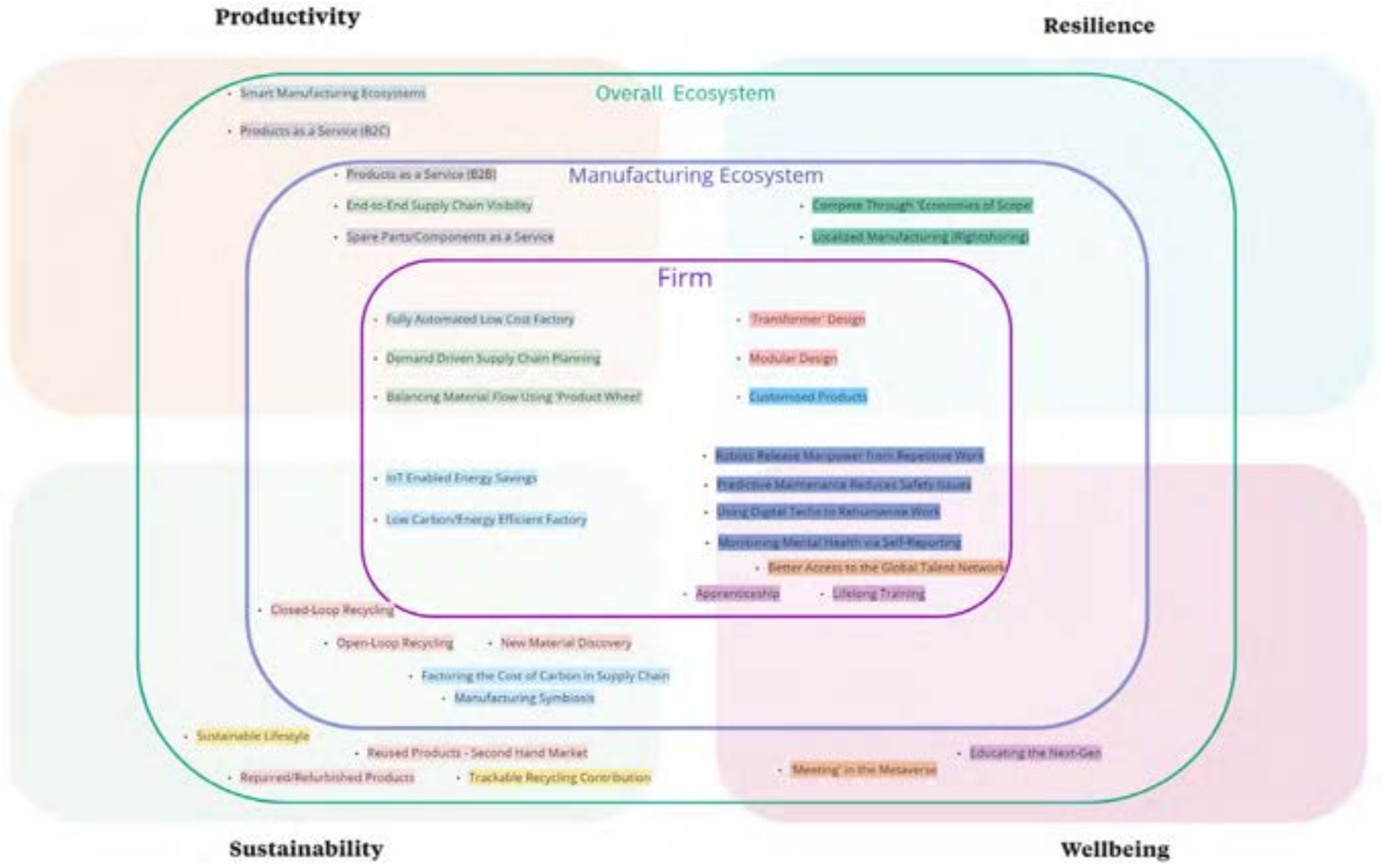
Although there are four scenarios being developed, it does not necessarily mean that UK manufacturing should move towards only one direction. The scenarios, visions and snapshots should be viewed collectively to deliver a system change at different levels of the ecosystem.

Firm-level refers to strategic and operational changes (lead to relevant snapshots) within the individual organisation

Manufacturing ecosystem refers to the changes that should take place at the supply chain/industry level, which requires a high level of collaboration between individual firms

Overall ecosystem includes additional stakeholders outside the manufacturing ecosystem, such as consumers, policymakers and supporting organisations (i.e., academics, and financial service providers).

Scenario Vision Snapshot



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Scenario 2040

Productivity Powerhouse

Turning UK manufacturing into a Productivity Powerhouse that focuses on maximising efficiency to produce more in less time without sacrificing quality. This enables the industry to improve its overall productivity and hence play a more dominant role in the global economy.

Visions and snapshots from the future

Vision 1 - Digital Manufacturing

- Fully Automated Low-Cost Factory
- Smart Manufacturing Ecosystems

Vision 2 - Digitally Enabled Integrated Offering

- Spare Parts/Components as a Service
- Products as a Service (B2B)
- Products as a Service (B2C)

Vision 3 - Smart End-to-End Supply Chain Management

- End-to-End Supply Chain Visibility
- Demand Driven Supply Chain Planning
- Balancing Material Flow Using ‘Product Wheel’

Scenario 2040
Productivity Powerhouse

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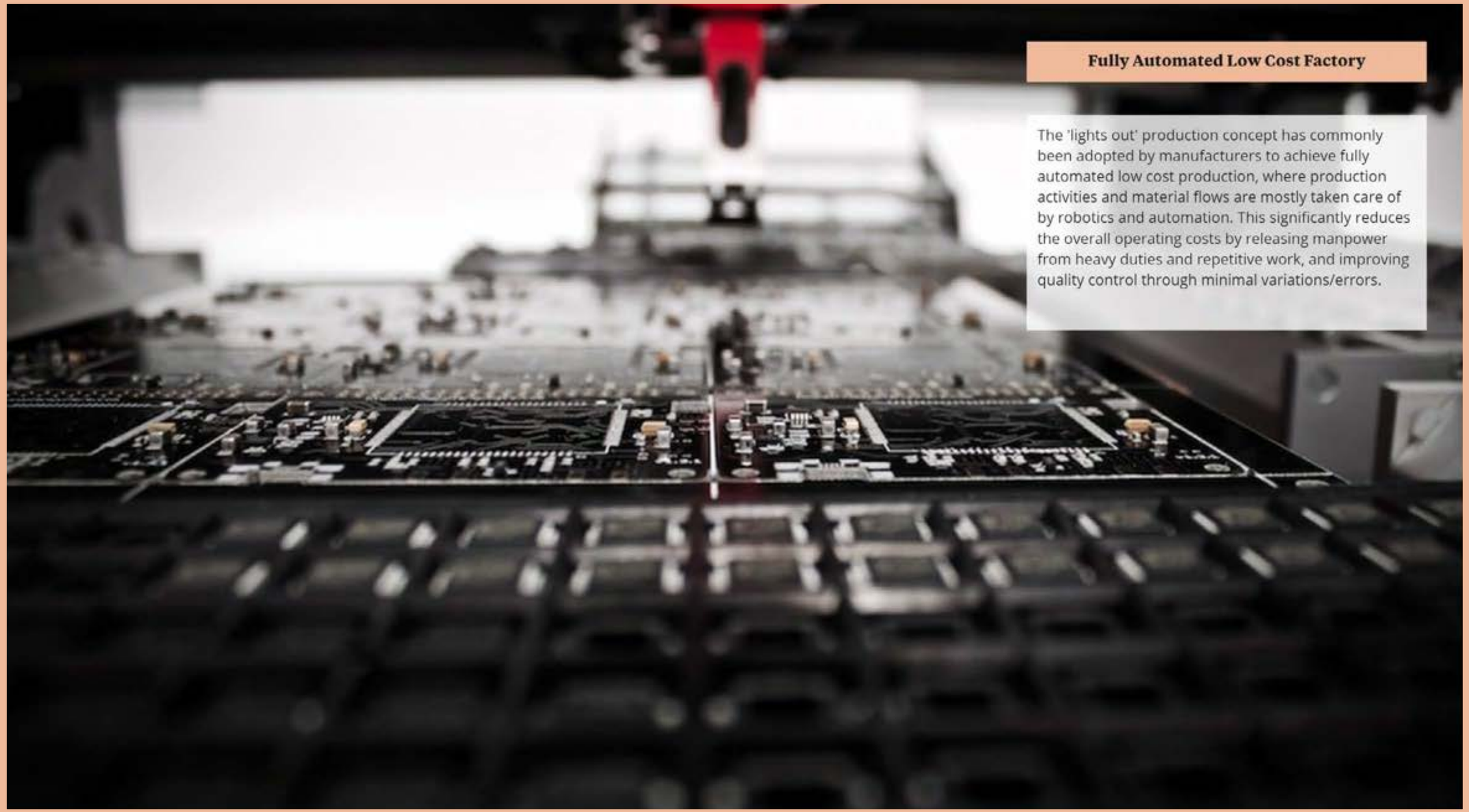
Vision 1

Digital Manufacturing

Digital technologies have been adopted at both the firm and ecosystem levels to improve the overall supply chain flows. The resource flow has been significantly improved through better production efficiency achieved in the factory, where manufacturing assets are automated to ensure that products are made to meet standard quality and within the shortest lead time possible. On the other hand better access to operations data and effective communications are assisted by IDTs, which enable closer relationships being established between different parties (i.e. production, supply chain, customer and talent) in the broad manufacturing ecosystems. Taking a collaborative approach in addressing manufacturing challenges enables the possible solutions to be formed and implemented effectively to tackle the national productivity challenges in the manufacturing setting.

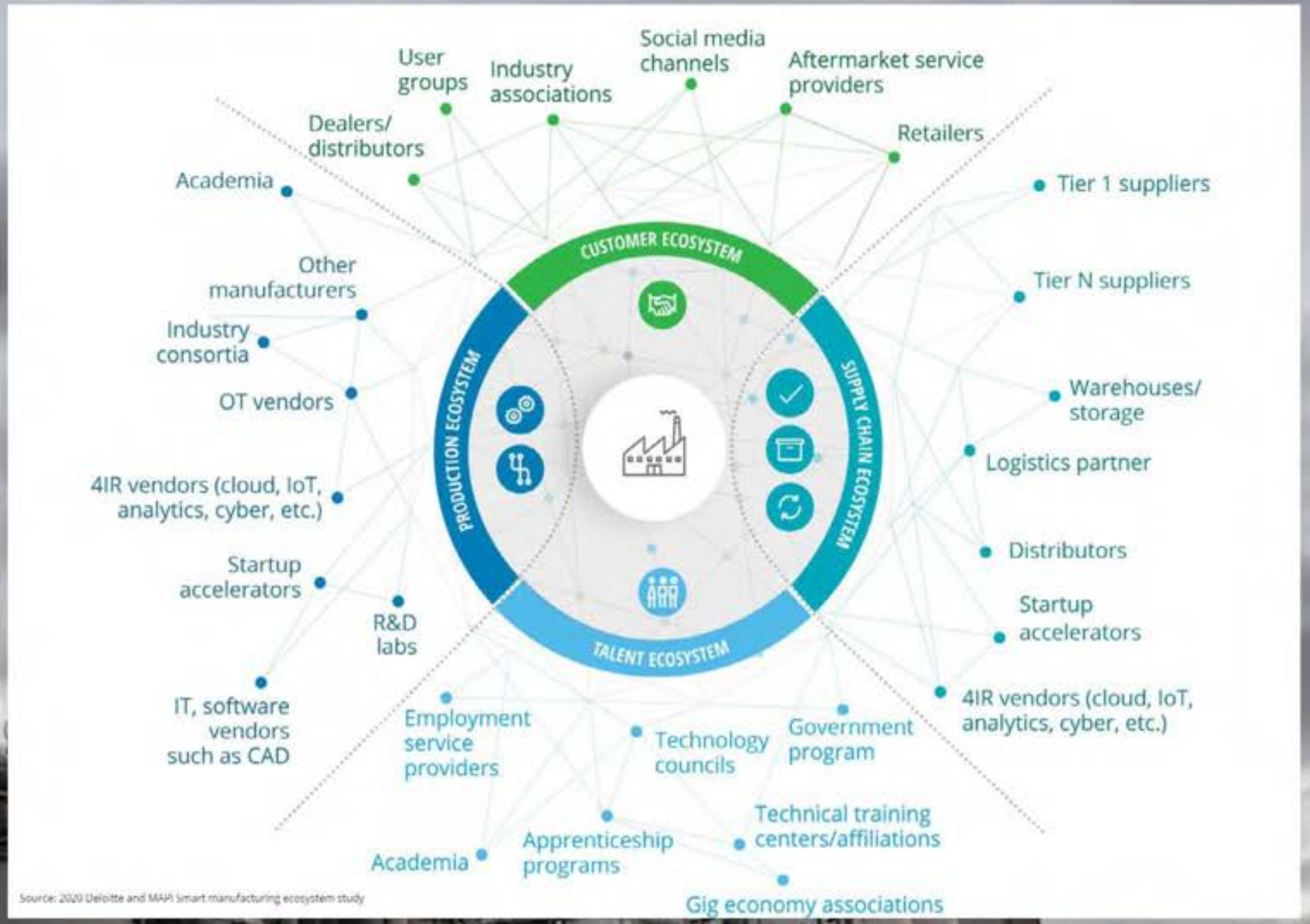


Fully Automated Low Cost Factory

The 'lights out' production concept has commonly been adopted by manufacturers to achieve fully automated low cost production, where production activities and material flows are mostly taken care of by robotics and automation. This significantly reduces the overall operating costs by releasing manpower from heavy duties and repetitive work, and improving quality control through minimal variations/errors.

Smart Manufacturing Ecosystems

Smart Manufacturing Ecosystems have been formed to bring different stakeholders together to create value for society by solving common challenges and delivering shared goals. These 'many-to-many' relationships are powered by IDTs, which enable manufacturers to access valuable information and assets in the broad network through better interactions with other stakeholders.



Scenario 2040
Productivity Powerhouse

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Vision 2

Digitally Enabled Integrated Offering

By 2040, the UK manufacturing industry has achieved a critical milestone in competing through value creation other than just cost optimization. Through the adoption of a servitized business model (a shift from product based to value based model by offering integrated product and service offerings), manufacturers are able to serve customers better by providing tailored/innovative offerings and through close collaborations. This enables firms to create a close tie with customers in the long term, which leads to stable cash flows and sustainable growth.

Spare Parts/Components as a Service

Spare parts suppliers are offering products as a service, so they retain the ownership of materials and are responsible for prolonging the product lifecycle through aftersales services (i.e. reuse, repair, remanufacture and recycle). This business model enables manufacturers to retain stable cash flow, build close ties with original equipment manufacturers (OEMs) and control material flows.

Products as a Service (B2B)

High value manufacturing machines/equipment can be acquired as a 'service' via an outcome-based contract. This enables the industrial customers to focus on their core operations, as the vendor is responsible for delivering the agreed outcome by keeping products in good working order. This business model is supported by IDTs such as the internet of things (IoT) to monitor the machine performance, and smart analytics to discover new trends based on historical data.

Car Sharing

Battery Sharing

Products as a Service (B2C)

Today, consumers do not own some of the products; instead they pay for the solutions delivered by the integration of physical products and associated services. This model allows them to enjoy the solution whenever/wherever needed and share assets with the community to reduce material consumption in the economy. The sharing economy is formed on the basis of the digital platforms that match demand with supply through better connectivity between assets and humans.

Scenario 2040
Productivity Powerhouse

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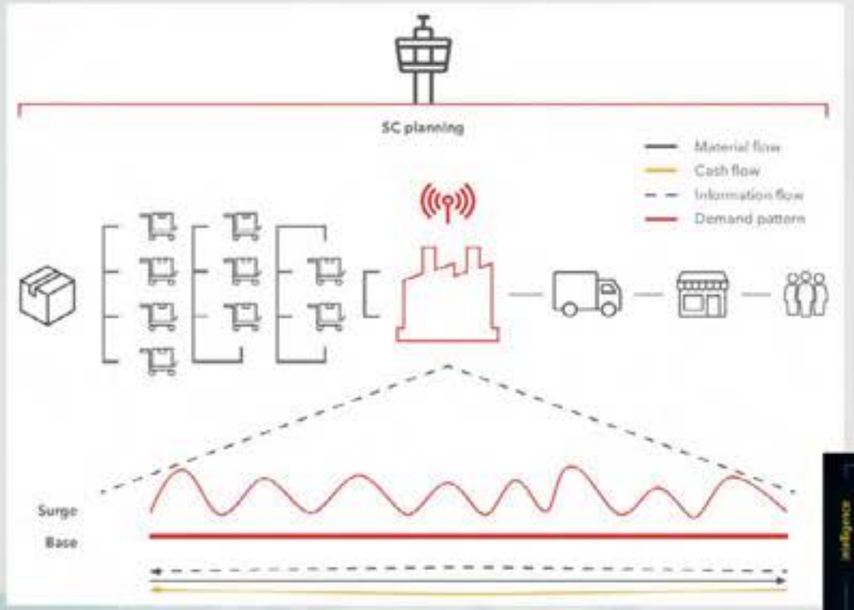
Vision 3

Smart End-to-End Supply Chain Management

The majority of UK manufacturers have taken an end-to-end approach in managing supply chains in which they are involved. In this way, the OEMs become critical coordinators, who play a vital role in recognizing the the different types of market demands and sending a set of stable demand signals to suppliers (mostly SMEs) in lower tiers. With the support of supply chain analytics and data sharing technologies, this significantly improves the overall visibility and enables everyone in the chain to thrive in a more stable business environment. Following the stable demand signals, demand/supply planning and production scheduling can be effectively managed to deliver value at the lowest possible cost as well as in the shortest lead time.

End-to-End Supply Chain Visibility

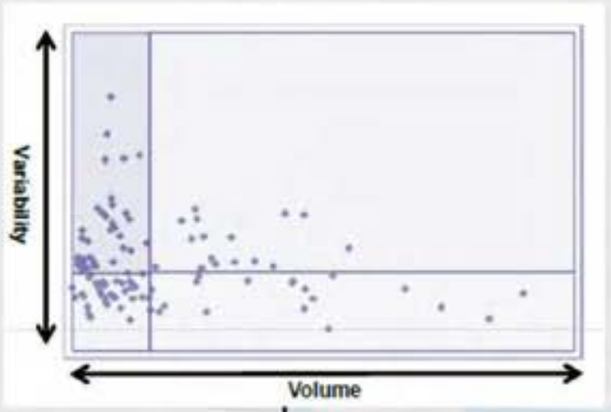
The Supply Chain Control Tower collects real time data from all entities to provide end-to-end visibility. Smart analytics are also applied to identify insights behind the data, which helps the OEMs to direct the lower tiers by sending clear and stable demand signals. It enables firms to uncover the burning issues in the end-to-end supply chains, and act quickly by pulling together relevant resources to address the issues.

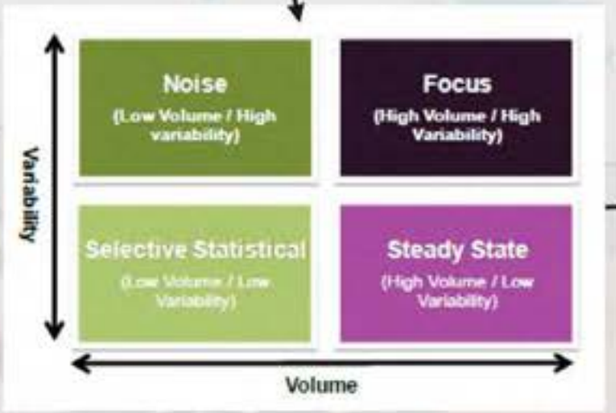


Supply Chain Control Tower Dashboard

Demand Driven Supply Chain Planning

Manufacturers have leveraged the power of data analytics in supply chain planning, which enables them to better recognize different demand patterns, and develop tailored supply chain practice to serve each type of demand. This helps manufacturers to manage their inventory at the optimal level (i.e. not too much or too little) to improve their cash flow and customer service level.

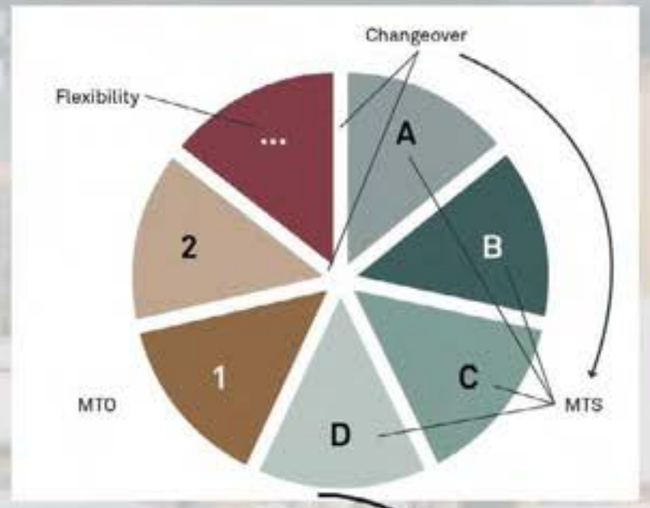


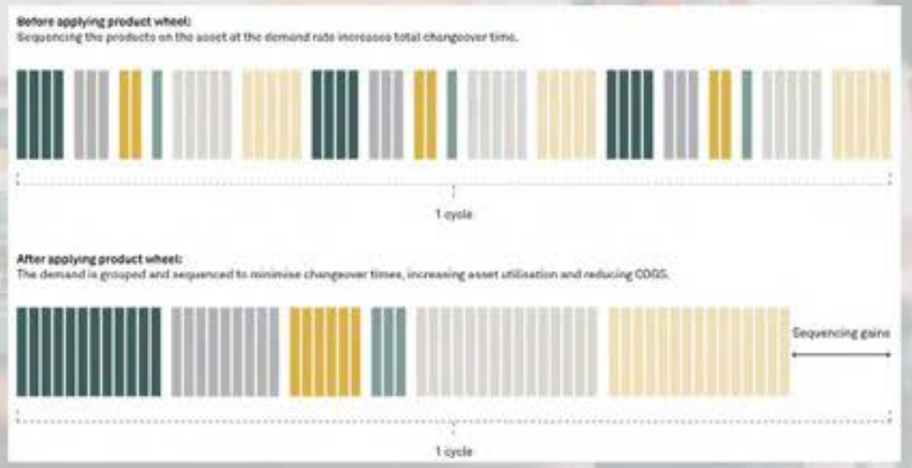


	Tailored Practices			
Function	Steady State	Selective Statistical	Focus	Noise
Sales	Minimise promotions	Avoid promotions	Drive volume through promotion in close collaboration with customer	Avoid promotions and validate why a SKU is in the portfolio
Marketing	Build SKU base	Increase volume base and consolidate SKUs	Build flexibility into the portfolio	Reduce SKU complexity
Planning	Statistically forecast	Statistically forecast	Manual forecast based on past history	Collaborative forecast with customer & commercial teams
Manufacturing	Minimise production cycle and production costs	Minimise / maintain production cycle	Maximise agility with a must respond mentality	Make to order
Procurement	Focus on quality and cost	Focus on quality and cost	Minimise order lead time	Cover variability with inventory

Balancing Material Flow Using 'Product Wheel'

Production schedule is commonly planned using the 'Product Wheel' concept, which allows products that belong to the same family (characterized by the demand pattern, shape, material, colour etc.) to be produced in the same slot. This largely reduces the time waste (change over time) throughout the process, hence improves the overall productivity.





Scenario 2040

Flexibility as the Standard

Flexibility as the Standard is a scenario where manufacturers compete through economy of scope by offering customized offerings and services. This allows firms to serve different types of market demands, which significantly enriches the UK supply base, making it more resilient ahead of any future global disruptions.

Visions and snapshots from the future

Vision 4 - Mass Customisation

- Customisation

Vision 5 - ‘Flexible’ Products

- Modular Design
- ‘Transformer’ Design

Vision 6 - Distributed Manufacturing

- Compete through ‘Economies of Scope’
- Localized Manufacturing (Rightshoring)

Scenario 2040
Flexibility as the Standard

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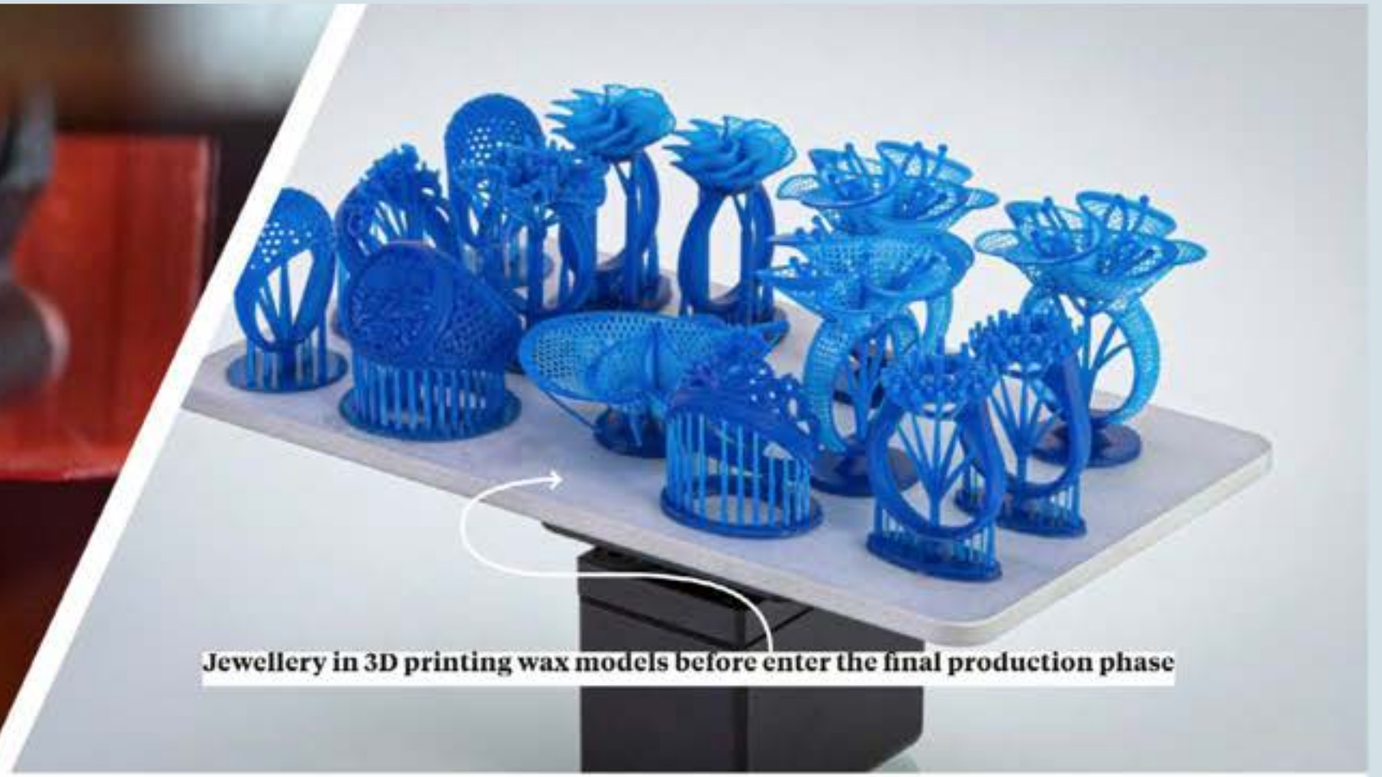
Vision 4

Mass Customisation

Customised offerings are available in different sectors such as food, healthcare, and automotive. This enables manufacturers to be more effective in delivering value for end customers, thus creating a unique selling point for their business and improving overall financial performance. With the support of digital technologies, customers are able to design tailored products with the support of manufacturers, and then send the product specification to be made.

Customisation

All products can be semi/fully customised to meet customer needs. This is powered by digital platform and 3D Printing technologies, which enables customers to send product specifications to vendors, and then the vendor makes the product on demand. This largely reduces the inventory costs for slow-moving products and more importantly enables customers to obtain customizable products to suit their needs.



Jewellery in 3D printing wax models before enter the final production phase

3D printed filament

Scenario 2040
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Vision 5

‘Flexible’ Products

Flexibility becomes a fundamental concept in the product design, in which products are designed in modularity and to serve different purposes. Adopting modular design in new product development improves the product’s lifecycle by building flexibility into the design, which allows end users to easily (i.e. D.I.Y) repair the product through spare part replacement. On the other hand, the ‘transformer’ design is applied to enable a product to be easily converted into a different form and function to serve different purposes, therefore saving consumers from having to buy multiple items to satisfy different requirements.

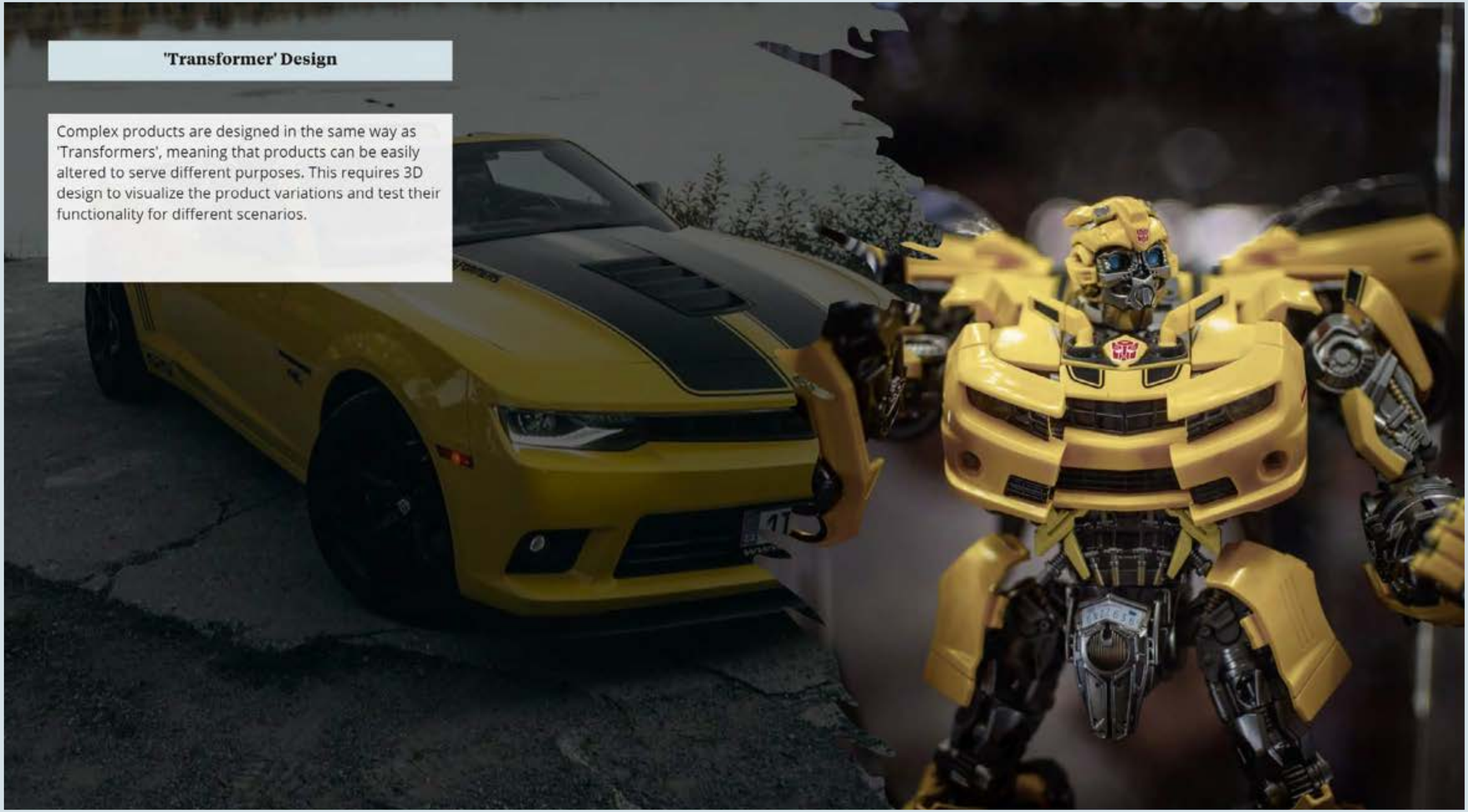
Modular Design

Modularity is built into the product development, in which any products can be divided into sub-parts that are manufactured through a standard process. This enables the users to configure the product according to their needs (a kind of customization) and broken parts can be easily replaced without any support from the vendor.

skin + sole = Shooz

'Transformer' Design

Complex products are designed in the same way as 'Transformers', meaning that products can be easily altered to serve different purposes. This requires 3D design to visualize the product variations and test their functionality for different scenarios.



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Vision 6

Distributed Manufacturing

By 2040, the distributed manufacturing business model has been established in the UK with the support of local manufacturers. This model brings the manufacturing supply chains closer to end markets by local sourcing and production. To be part of the distributed manufacturing ecosystems, manufacturers have to unleash their potential to serve different markets by leveraging their production and R&D capabilities. In this way, businesses become more resilient ahead of any future global disruptions as supply chains are locally based (through rightshoring) and business risks are minimized when competing through ‘economies of scope’ (i.e. serving multiple markets rather than focusing on a niche market). The management of a distributed manufacturing network requires the support of advanced digital technologies to coordinate supply chain flows between different parties, which is critical in delivering the guaranteed customer service level.

Compete through 'Economies of Scope'

Manufacturers are competing through 'economies of scope' by serving diverse markets through their current capabilities (i.e. manufacturing assets, digital technologies and skilled workers). Digital platforms are the marketplace for firms to showcase their capabilities and identify potential collaborators.

Localized Manufacturing (Rightshoring)

Products are sourced and produced locally through the Distributed Manufacturing model, which brings supply chains closer to end users and, more importantly, boosts the local economy through increased demands and job opportunities. All supply chains' entities are digitally connected and coordinated to fulfil customer orders within the shortest lead time at the lowest possible cost. With local-based supply chains, the risk of exposure to global disruptions is minimized.

Scenario 2040

Sustainability Champion

In the scenario ‘Sustainability Champion’, UK manufacturing has achieved some sustainability goals through the significant improvement of resource and energy efficiency across end-to-end supply chains. This is facilitated by the adoption of circular economy principles and digital technologies, which enable firms to maximize the value of materials through the entire lifecycle.

Visions and snapshots from the future

Vision 7 - Responsible consumption

- Sustainable Lifestyle
- Trackable Recycling Contribution

Vision 8 - Mining Materials from Current Ecosystems

- Reused Products - Second Hand Market
- Repaired/Refurbished Products
- Open-Loop Recycling
- Closed-Loop Recycling
- New Material Discovery

Vision 9 - Carbon-Zero Manufacturing Ecosystems

- IoT Enabled Energy Savings
- Factoring the Cost of Carbon in the Supply Chain
- Low Carbon/Energy Efficient Factory
- Manufacturing Symbiosis

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Vision 7

Responsible Consumption

Consumer purchasing decisions are driven by both sustainability and financial factors. This requires a greater level of supply chain visibility, so the relevant data such as carbon footprint, material ingredients, and country of origin can be revealed to consumers to enable well-informed decision making. Moreover, consumers have a better understanding of how they could contribute to the sustainability goal of the entire ecosystem. For example, an initiative has been taken to track individuals' contributions to material recycling, which is achieved through tracking technologies. This shift of mindset on the demand side is a critical driver for adopting sustainable practices on the supply side.

Sustainable Lifestyle

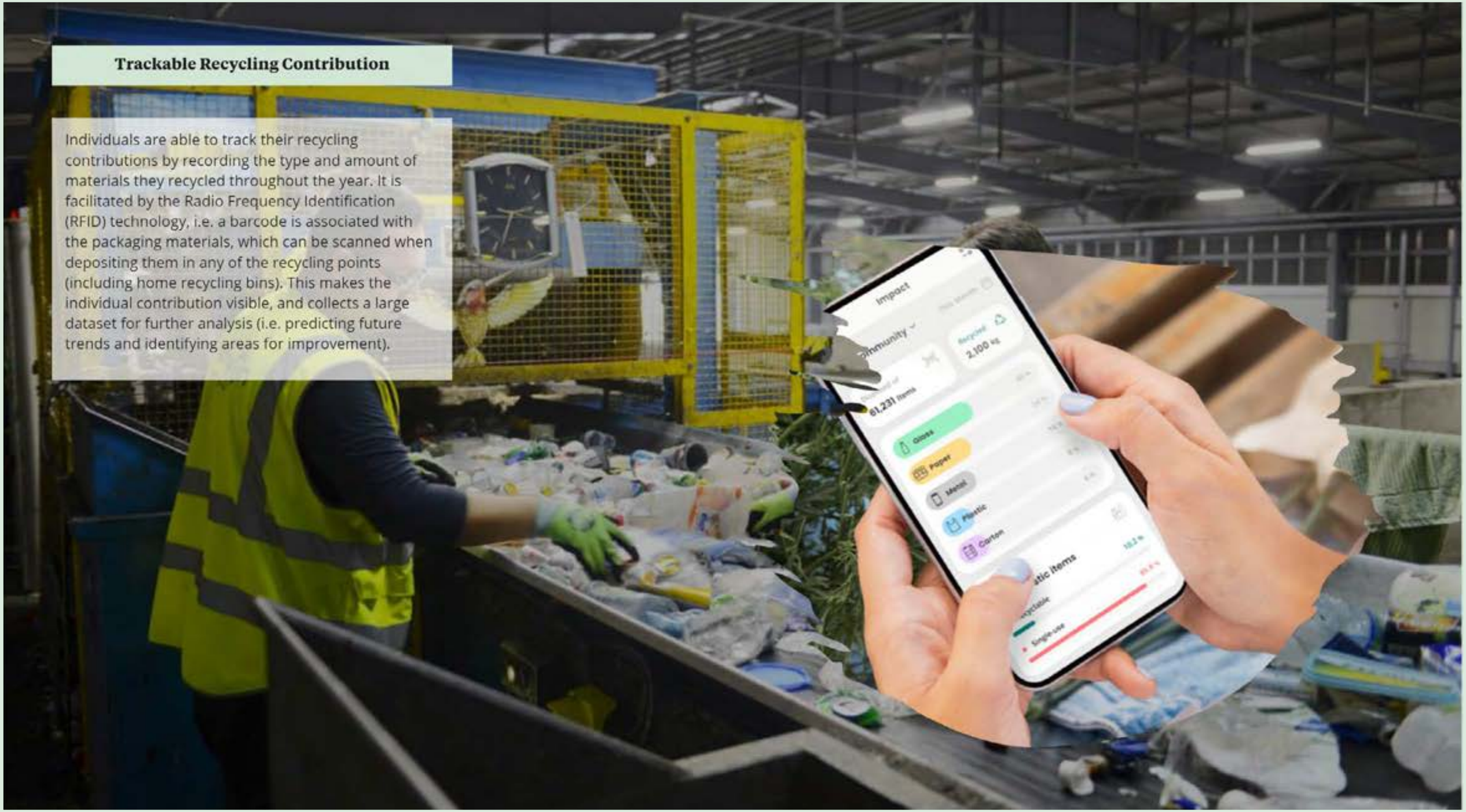
Consumer buying behaviours are driven by both the cost and sustainability. The supply chain data associated with a product is gathered through tracking and tracing digital technologies, which help to store data and make it readily visible to consumers to facilitate their purchasing decisions. This shift in the demand side has driven the suppliers/vendors to take a proactive approach to achieving sustainable growth.

Garments Facts

Total number Synthetic chemicals	112
Weight of chemicals per 100g	25g
Synthetic dye	Red F5-B
Date of Manufacture	21/04/2022
Factory (cutting/sewing) Energy Source	100% Coal
Can be worn (minimum) Quality	40 times
Total distance (km) Supply Chain	25,432
Number of Countries visited	3
Total number Materials Used	2
Fabric	cotton
Trim	cotton
Thread	(plastic) polyester
Zip/Buttons	n/a
Total shed per 6kg wash Microfibres	137,951
Cambodia average pcm ($) Textile Workers Pay	250
Percentage of living wage	45%

Trackable Recycling Contribution

Individuals are able to track their recycling contributions by recording the type and amount of materials they recycled throughout the year. It is facilitated by the Radio Frequency Identification (RFID) technology, i.e. a barcode is associated with the packaging materials, which can be scanned when depositing them in any of the recycling points (including home recycling bins). This makes the individual contribution visible, and collects a large dataset for further analysis (i.e. predicting future trends and identifying areas for improvement).



Scenario 2040
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Vision 8

Mining Materials from Current Ecosystems

To optimize the material efficiency in the entire ecosystem, Circular Economy principles such as reuse, repair, remanufacture and recycle have been widely adopted by manufacturing firms to support sustainable growth by maximizing the value of materials that are currently in circulation.

This requires collaborations between different parties (i.e. industrialists, consumers, policymakers) to tackle social (how can we convince people to buy 'old' products?), economic (how can we reduce the costs of refurbished/recycled/remanufactured materials?), operational (how do we take a system approach in addressing supply chain issues?), legal (what legislation needs to be in place to ensure fair trade?), and political (what policy changes are needed to support the UK's Net Zero agenda?) challenges.

Reused Products - Second Hand Market

The second-hand market flourishes as consumers become aware of the sustainable growth, and are willing to buy, rent, share and exchange products that are still in good condition. There are several large digital platforms to act as the marketplace for matching demand with supply.

Repaired/Refurbished Products

Nowadays, consumers are buying repaired/refurbished products more often than before. These products are re-processed by certified vendors and offered with a 3-5 year warranty. This significantly reduces the waste ending up in landfill, and improves material and energy efficiencies throughout supply chains as most components are not produced from scratch. More importantly, retaining products in the economic system reduces our reliance on virgin materials.

Open-Loop Recycling

The end of life products are dismantled following the industry's best practice, and the components are separated into recycled contents (can be used as feedstocks to other sectors) and waste (disposal of into the landfill). The recycled contents are traded on the regulated digital platform, where all the essential information (i.e. country of origin, chemical composites, quality and quality etc.) are available for potential buyers.

Closed-Loop Recycling

The end of life products are 100% recycled by the OEMs in some manufacturing sectors (i.e. metal, chemical and textile) as they have a great knowledge of the products (i.e. chemical composition engineering mechanisms, quality, etc.). Supply chain integration is essential in this model, as material suppliers need to work closely with other players in the ecosystem to form a circular supply chain. This requires a high level of connectivity and traceability, which is facilitated by the latest tracking technologies such as RFID and cloud computing, that document the data throughout the lifecycle of products.

New Material Discovery

New material discovery has reached a mature stage, so consumers are able to access products that are made from synthetic materials. The development process is powered by 3D modelling and machine learning to make, select and test candidate materials for further development. Using synthetic materials in manufacturing reduces our reliance on virgin raw materials and provides more sustainable options (i.e. biodegradable materials).

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Vision 9

Carbon-Zero Manufacturing Ecosystems

Carbon emission reduction drives the operating model design in the overall manufacturing ecosystem, where necessary changes need to take place at different levels (i.e. firm, supply chain, ecosystem) to accomplish the goal. At the firm level, it is common that IoTs have been adopted in the factory to monitor and improve the energy efficiency of the manufacturing assets. In addition, the production waste is systematically examined to identify the remaining value (i.e. using by-products as a feedstock for other processes/businesses). At the supply chain level, the carbon emissions are monitored from end-to-end, which provides a useful indication on how different parties should work together to identify the main contributing factors. Factoring the cost of carbon within supply chain management enables firms to take a collaborative approach in addressing greenhouse gas (GHG) emissions, which ultimately supports the Net Zero goal.

IoT Enabled Energy Savings

Most manufacturing plants have adopted IoT to construct a virtual network that connects all assets (i.e. devices and machines over the internet). This helps the factory manager to gain an overview of energy consumption across the entire factory. Moreover, the data indicates the real time energy consumption of each machine for monitoring purposes, which helps to identify areas that suffer energy loss and also inform immediate actions to improve energy efficiency.

Factoring the Cost of Carbon in Supply Chain

Today, carbon footprints (i.e. production and logistic transportation) embedded in any products can be tracked throughout end-to-end supply chains. The data is captured and stored using RFID technology and cloud computing storage, which makes the data easily available for all entities in the supply chain, including end consumers. This enables manufacturers to monitor their carbon footprint and helps consumers to make responsible consumption choices.

Low Carbon/Energy Efficient Factory

Low carbon production has become common practice in UK manufacturing, where most plants have achieved energy sufficiency by recovering energy from production wastes. This forms a closed-loop system on site that allows firms to reduce their dependency on external energy supply, and also reduce the amount of on-site emissions and landfill waste.

Steel plant to install waste heat recovery system to turn waste heat into electricity power

Turning potato peels into fertilizer

Install photovoltaic system to generate power from sunlight

Manufacturing Symbiosis

With joint efforts between the government and industry, the Manufacturing Symbiosis ecosystem has been practised in the UK to enable the energy and by-products exchange between different sectors/businesses. This is powered by a government-regulated digital platform, which serves as a marketplace to match potential demands with supplies. The platform links with a mega database that documents the information of each tradable product (e.g. original supplier, type of waste, chemical composition and potential applications).

Scenario 2040

Happy and Sustainable Workforce

Happy and Sustainable Workforce is a scenario that focuses on addressing the issues around wellbeing in manufacturing. In 2040, the industry becomes people oriented, and offers customizable support to employees to create a workplace that diversity, equality, and inclusion.

Visions and snapshots from the future

Vision 10 - Better Health and Wellbeing

- Robots Release Manpower from Repetitive Work
- Predictive Maintenance Reduces Safety Issues
- Monitoring Mental Health via Self-Reporting
- Using Digital Techs to Rehumanise Work

Vision 11 - Sustainable Talent Development

- Lifelong Training
- Apprenticeships
- Educating the Next Generation

Vision 12 - Workforce is a Part of the Digital Ecosystem

- Better Access to the Global Talent Network
- ‘Meeting’ in Metaverse

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Vision 10

Better Health and Wellbeing

In 2040, manufacturing firms are taking a people-oriented approach in designing and managing the workplace. To create a better working environment that supports the wellbeing of employees, firms have adopted digital technologies in the factory to address human-related issues such as releasing human workers from dangerous tasks (i.e. heavy lifting and unpredictable machine breakdowns) and re-engineering the work process that then enables employees to work comfortably with digital technologies. Moreover, senior leadership has paid more attention to the employees’ health and wellbeing, such as monitoring the stress level of each employee by adopting a self-reporting system.

Robots Release Manpower from Repetitive Work

By 2040, most manual work in the manufacturing plant will be carried out by robots, which releases the workforce from heavy lifting and repetitive jobs. This largely reduces the health and safety hazards in plants and enables people to focus on higher value work. Moreover, it helps to ease the pressure of labour shortage in the industry.

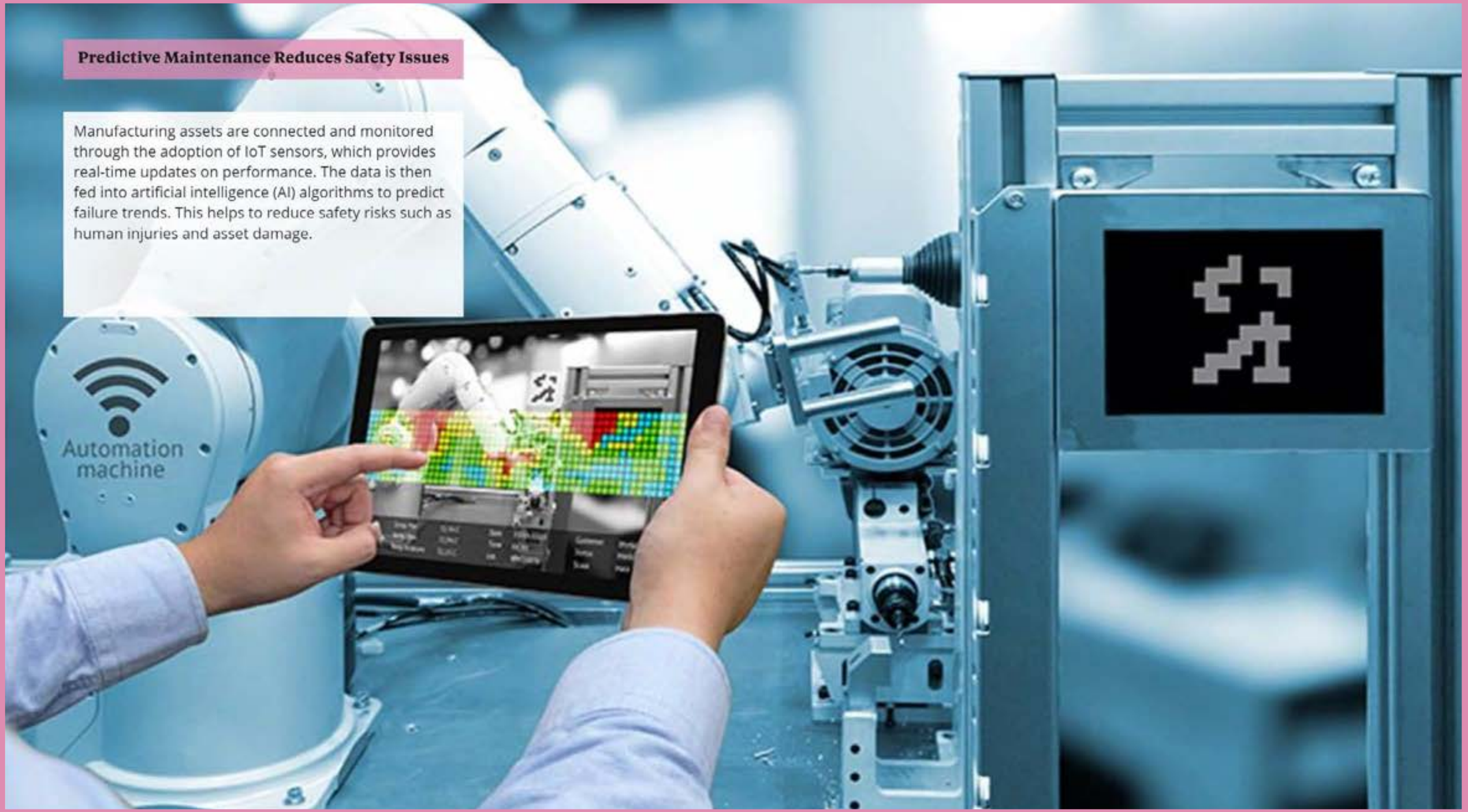
Robots do the heavy lifting in the factory

Release experienced welders to focus on high value wor

Mobile robots transport goods in the factory

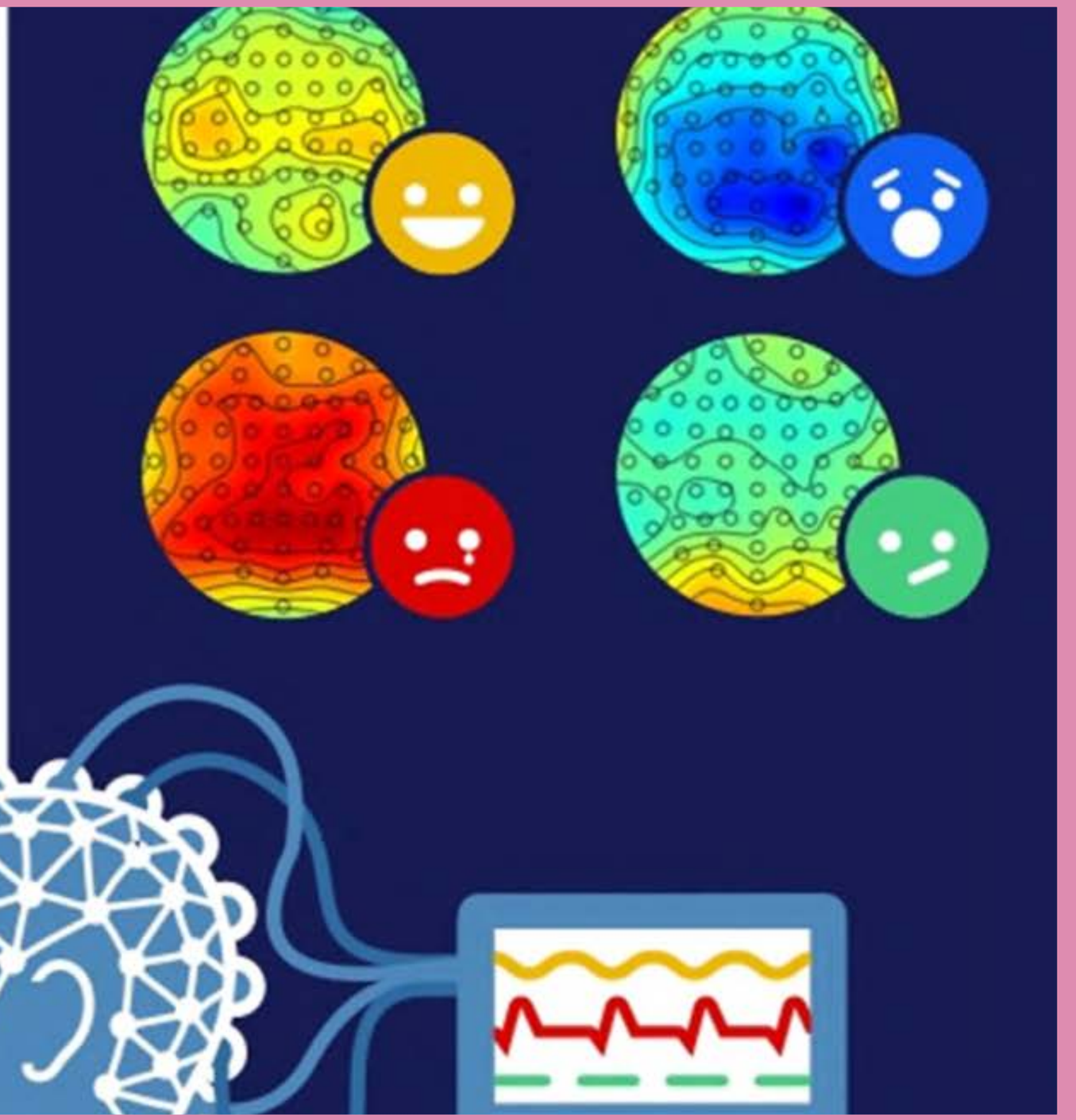
Predictive Maintenance Reduces Safety Issues

Manufacturing assets are connected and monitored through the adoption of IoT sensors, which provides real-time updates on performance. The data is then fed into artificial intelligence (AI) algorithms to predict failure trends. This helps to reduce safety risks such as human injuries and asset damage.



Monitoring Mental Health via Self-Reporting

With the advanced digital technologies, employers are able to monitor the mental health of workforces through interactive working systems (i.e. corporate team working platform where employees could submit emojis that reflect their emotion throughout the working day). This enables employers to identify workforces who are suffering from mental stress (i.e. someone who reports persistent low moods) and provide proper support where needed, such as taking days off and directing them to personalized coaching or therapy.



Using Digital Techs to Rehumanise Work

By 2040, digital technologies are not only adopted to improve work efficiency through greater level of automation, they help to improve the experience of the workplace. Manufacturing firms understand that not all parts of jobs can be automated, and digital technologies provide opportunities to redesign jobs and re-engineer processes/workflows to enable people to focus on the tasks that are well-suited for humans, such as intuitive decision-making, relationship building and problem-solving.

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Vision 11

Sustainable Talent Development

The majority of manufacturing firms have taken initiatives to address the skill gaps in the areas of sustainability and digitalization. To ensure employees grow towards the firm’s business objectives, a lifelong training programme is offered by most employers to ensure that employees are able to access all kinds of training courses to support their daily responsibilities. The training covers the relevant topics and is regularly updated in line with the company’s development plan. An apprenticeship programme also becomes more popular in the manufacturing industry as this is an effective way to address the skill gap. Through this programme, firms are able to train young people in a tailored way, so they are prepared for a full-time role on completion of the apprenticeship.

To support long term sustainable talent development, the higher education system in the UK has also considered providing practical and relevant course content for school age children to be able to explore different elements during the early stages of their education.

Lifelong Training

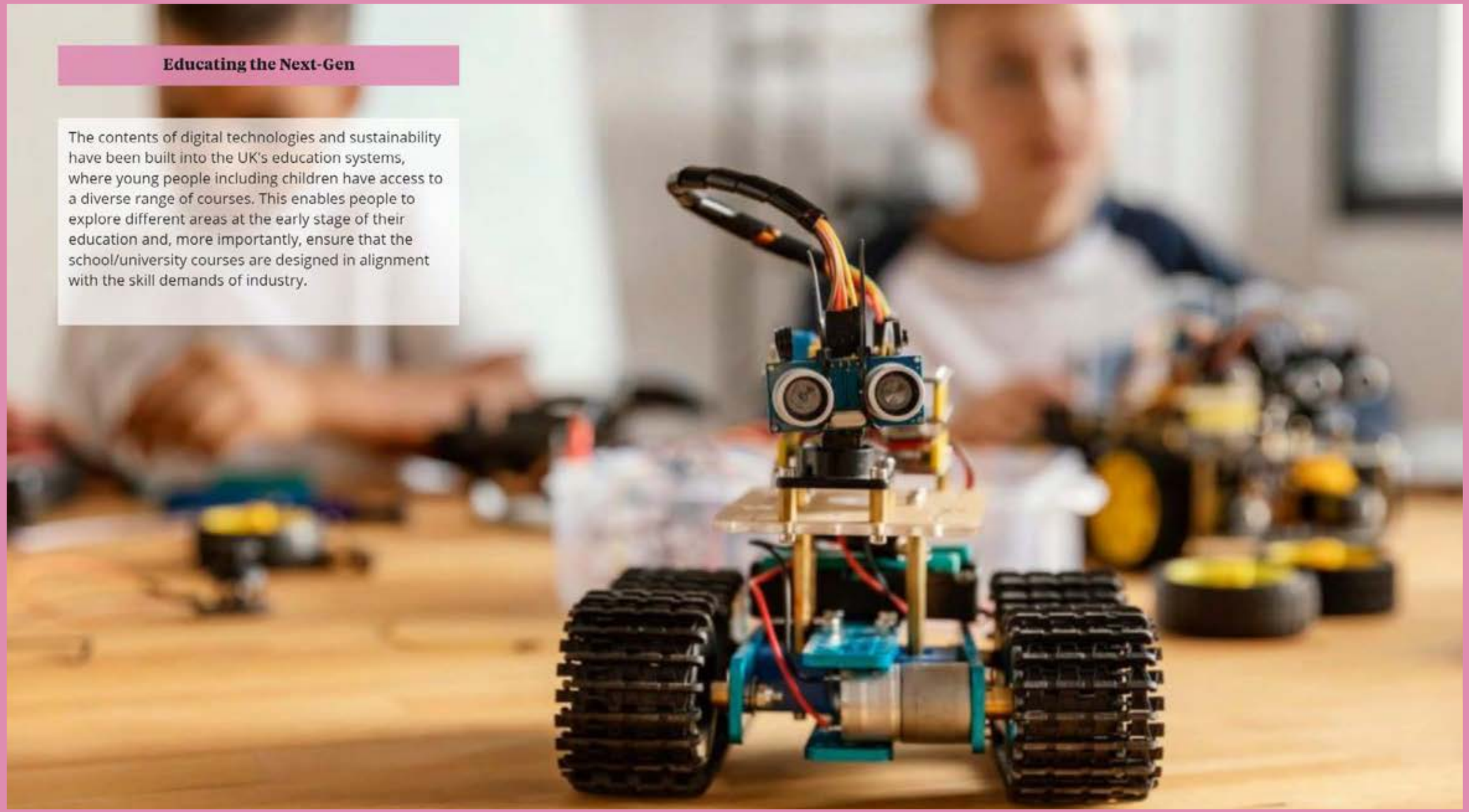
A lifelong training programme in most manufacturing firms has become a main platform to upscale employees and support them in making the transition into the digital world as the company progresses along the digitalization journey. The training programme is updated regularly to ensure that workforces are developed to support the future vision (i.e. sustainability, digitalization, etc.) of the firm, so no one is left behind. The training is provided through mixed activities (i.e. lectures, seminars, workshops and technical mentorship) so people are able to obtain rounded support.

Apprenticeship

Apprenticeship has become a popular way of matching people with an ambition to companies with a vision. This is a win-win situation as it enables firms to address the skill gap by developing talents through the programme, and on the other hand, enables people to gain hands-on experiences that provide a better fit with firms' skill demands. As the demand for digital and sustainability skills keeps growing, first-hand experiences become more important in performing the job properly.

Educating the Next-Gen

The contents of digital technologies and sustainability have been built into the UK's education systems, where young people including children have access to a diverse range of courses. This enables people to explore different areas at the early stage of their education and, more importantly, ensure that the school/university courses are designed in alignment with the skill demands of industry.



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Vision 12

Workforce is a Part of the Digital Ecosystem

To embrace diversity, inclusion, and equality among workforces, firms have adopted digital technologies to support hybrid working post-COVID 19. This gives manufacturing firms better access to the global talent pool, as they are able to hire people based in any location, while this flexible working option allows employees to have more career possibilities. In addition, the advanced development of virtual reality (VR) contributes to the establishment of a ‘Metaverse’, where people can meet online for work collaborations and, more importantly, real time operations of the plant could be visualized online.

Although the production line cannot be taken home, the workforce that is taking care of it can work remotely to monitor its performance and take actions where appropriate to ensure process efficiency.

Better Access to the Global Talent Network

Hybrid working has become common practice, which enables firms to embrace the diversity, equality and inclusion among employees. This allows employers to access the talent network all over the world, which addresses the pressure from skill shortages in the UK. On the other hand, employees are able to enjoy the work from any place in the world, which provides them with more career possibilities.

'Meeting' in Metaverse

Through the deployment of VR and other supporting digital technologies, people are able to visualize real-time operations of the factory/warehouse at home through the internet. This significantly improves the overall flexibility of the workforce, especially those who work on the production line and inventory. More importantly, this provides greater visibility to senior managers who may not be present on site every day, to obtain an instant update on daily operations.

References

1. Christopher, M. (2006). Logistics & supply chain management. Pearson UK
2. Zhang, W., Godsell, J. and Driffield, N. (2021) Supply Chain Productivity: A missing link?, University of Warwick, UK
3. Department for Business, Energy & Industrial Strategy (BEIS) (2017) Made Smarter 2017 Review, UK Gov
4. Cambridge Industrial Innovation Policy (2023) Why manufacturing supply chains matter and how to revitalise them (Commissioned by BEIS), IfM Engage, University of Cambridge
5. Franconi, A., Ceschin, F., Godsell, J., Harrison, D., Mate., O and Konteh., T, (2022) 2050 Circular Metal Visions, Brunel University, UK
6. Mont, O., Neuvonen, A. and Lähteenoja, S., 2014. Sustainable lifestyles 2050: stakeholder visions, emerging practices and future research. Journal of Cleaner Production, 63, pp.24-32
7. Foresight (2013). The Future of Manufacturing: A new era of opportunity and challenge for the UK Project Report, The Government Office for Science, London
8. Foresight (2013). Manufacturing best practice and UK productivity, The Government Office for Science, London
9. Foresight (2013). Public images of manufacturing in the UK: the current situation and future prospects, The Government Office for Science, London
10. Foresight (2013). Future of Mobility: Trends in manufacturing and global supply chains and their impact on UK freight, The Government Office for Science, London
11. World Economic Forum (2016) Manufacturing Our Future Cases on the Future of Manufacturing
12. World Manufacturing Foundation (2021) Digitally Enabled Circular Economy
13. Gov UK (2013) The future of manufacturing: a new era of opportunity and challenge for the UK
14. UK Manufacturing Association (2021) Investing in advanced manufacturing is investing in levelling up
15. Department for Business, Energy & Industrial Strategy (BEIS) (2021) Net Zero Strategy: Build Back Greener
16. World Manufacturing Foundation (2021) Net Zero Challenge: The supply chain opportunity
17. World Manufacturing Foundation (2021) Raising Ambitions: A new roadmap for the automotive circular economy
18. World Manufacturing Foundation (2021) Beyond Supply Chains: Empowering Responsible Value Chains
19. Cambridge Industrial Innovation Policy (2015) Industrial Evolution: Making British Manufacturing Sustainable, IfM Engage, University of Cambridge
20. Cambridge Industrial Innovation Policy (2017) Emerging trends in global advanced manufacturing: Challenges, Opportunities and Policy Response, IfM Engage, University of Cambridge
21. Cambridge Industrial Innovation Policy (2013) Next-Manufacturing-Revolution: Non-Labour Resource Productivity and its potential for UK manufacturing, IfM Engage, University of Cambridge
22. KPMG (2017) Rethink manufacturing: Designing a UK industry strategy for the age of industry 4.0
23. BSI (2017) Acceleration of digital innovation by UK manufacturing supply chains
24. Make UK (2022) Operating without Borders - Building Global Resilient Supply Chains
25. Department for Digital, Culture, Media & Sport (2021) Assessing UK's regional digital ecosystems
26. Culot, G., Orzes, G., Sartor, M. and Nassimbeni, G., 2020. The future of manufacturing: A Delphi-based scenario analysis on Industry 4.0. Technological forecasting and social change, 157, p.120092
27. London Economics (2019) Industry 4.0 and the future of UK space manufacturing
28. Accenture (2020) The race for digital operations transformation: The time for experimenting is over
29. Barclay (2017) Future-proofing UK manufacturing: Current investment trends and future opportunities in robotics and automation
30. Make UK (2022) UK Manufacturers are leading the charge in green revolution
31. Make UK (2022) Levelling Up: Bridging the gap between policy and progress
32. Make UK (2022) Operating without Borders - Building Global Resilient Supply Chains
33. Department for Business Innovation & Skills (2014) Strengthening UK supply chains: Good practice from industry and government
34. KPMG (2021) Future of Supply Chains: Road to Everywhere

References

35. Accenture (2022) From disruption to reinvention: The future of supply chains in Europe
36. Cambridge Industrial Innovation Policy (2013) Next-generation supply chains: Making the right decisions about digitalisation, IfM Engage, University of Cambridge

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