Digital Manufacturing

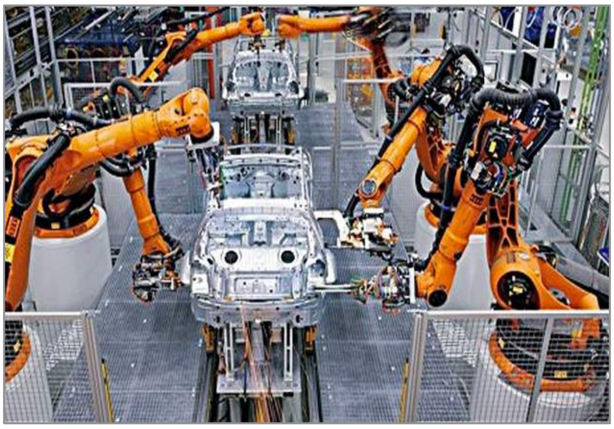
The digital manufacturing sector is comprised of 18 sub-sectors across a variety of industries

The sector produces 35 per cent of UK exports - £170 billion in 2015

Digital manufacturing employs 6.3 per cent of the UK workforce (1.9 million people)

The sector is a major focus for Innovation UK support (£137m in 2016/17)

Digital technologies have the potential to create huge amounts of data to better coordinate the supply chain



Digital technologies will generate huge amounts of data and provide major opportunities for transformation, new products and new business models in the digital manufacturing sector. Digital manufacturing is generally characterised by the assembly of many hundreds or thousands of parts. Coordination of production activities within and between factories, and the provision of parts throughout the supply chain, can be enhanced by digital technologies. Digital technologies offer considerable opportunities for greater productivity and customisation – providing economies of scale and scope.

Introduction

The digital manufacturing sector was defined by UK government in their 2012 to 2015 High Value Manufacturing strategy document[1] as being comprised of 18 sub-sectors, these include:-

Aerospace, defence and space	Automotive
Biotechnology	Built environment
Chemicals	Consumer goods
Digital economy, communications and security	Electronics
Energy	Food
Marine (including under-sea)	Medical
Mining	Nuclear
Oil and gas	Pharmaceuticals
Retail, entertainment and consumer goods	Rail

Probably due to its diverse nature there is a paucity of data about digital manufacturing and many studies and government policy documents present statistics for the entire manufacturing sector rather than the particular contribution of digital manufacturing.

The Technology Strategy Board stated that *digital manufacturing* produced 35 per cent of UK exports in 2010[2]. In 2010 the *manufacturing* sector produced 46 per cent (£204 billion) of UK exports (£443 billion)[3]. The sector therefore provides 76 per cent of total UK manufacturing exports. Total UK manufacturing exports rose to £224 billion in 2015. If digital manufacturing maintained its share the value of exports would be £170 billion in 2015.

[1] https://www.gov.uk/government/publications/high-value-manufacturing-strategy-2012-to-2015

[2] Technology Strategy Board. 2012. High Value Manufacturing https://www.gov.uk/government/uploads/system /uploads/attachment_data/file/362294/High_Value_Manufacturing_Strategy_2012-15.pdf

[3] ONS, Trade in Goods, series BPAN, BQBD, IKBH, IKBI

The manufacturing sector employs around 2.6 million people in 2015[4]. Pro-rata with the share of exports this would suggest that the digital manufacturing sector employs 1.9 million people. There were 31 million people in work in 2015[5], the digital manufacturing sector therefore comprised 6.3 per cent of the UK workforce. Innovate UK report the digital manufacturing sector as having 250,000 businesses[6].

The very diverse nature of the digital manufacturing sector means that a number of existing Innovation UK strategic objectives and initiatives focus on the sector as a whole and some of the 18 sub-sectors that comprise digital manufacturing. For example the High Value Manufacturing catapult was launched in October 2011 with a clear mission to become a "catalyst for the future growth and success of manufacturing in the UK. We help accelerate new concepts to commercial reality to create a sustainable high value manufacturing future for this country"[7].

Some of the other Catapults in the UK focus on specific sub-sectors. For example the Energy Systems and Offshore Renewable Energy Catapults (the energy sub-sector), Precision Medicine and Medicines Discovery Catapults (the medicine sub-sector), Smart Cities Catapult (the built environment sub-sector) and the Transport Systems Catapult (automotive and rail sub-sectors).

At a more strategic level it is notable that Innovation UK will be devoting 24 per cent (£137 million) of its core budget for 2016/17 (£561 million) to manufacturing and materials. The objective is to focus on advancing manufacturing readiness so R&D and technology developments can be delivered at scale across a range of sectors to increase productivity and grow to capture the value in the UK. Activities will include a number of competitions, including two on manufacturing and materials, one on advanced manufacturing and one on manufacturing readiness focussing on later-stage innovation.

The diverse nature of the digital manufacturing sector creates a difficulty in providing a succinct overview. Accompanying sector briefing papers from this study have examined sectors defined more tightly. Indeed, several provide insights to some of the digital manufacturing sub-sectors (e.g. the transport briefing paper covers automotive and rail sub sectors, health and well-being considers the medical sub-sector and the creative industries briefing includes parts of the entertainment and consumer goods sub-sectors).

This review therefore commences with a broad consideration of the potential benefits of digital technologies to high value manufacturing. This includes a consideration of forecasts for utilisation of some of the key technologies (RFID, wearables and robotics) that could impact on future growth. Two sub-sectors not covered by previous studies - Energy and Food - are examined to provide a flavour of future prospects and opportunities. The paper concludes with a consideration of catalysts, disruptors and opportunities.

Digital technologies and high value manufacturing

High value manufacturing operations are generally characterised by the assembly of parts and/or production of goods. Manufacturing production can involve assembling hundreds and in some cases thousands of parts. For example a passenger vehicle is typically comprised of 6,000 mechanical, electro-mechanical and electronic parts. Assembly requires approximately 20,000 operations/actions per vehicle. These sequential and concurrent assembly operations must be synchronised with a similar number of logistical operations, frequently with a global reach, to ensure that products meet customer specifications within agreed time frames. Digital technologies offer considerable opportunities for greater productivity and customisation – providing economies of scale and scope.

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[4] House of Commons Library. 2015. Manufacturing: Statistics and policy.

[5] ONS. 2016. UK labour market August 2015. http://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/bulletins/uklabourmarket/2015-08-12#main-points-for-april-to-june-2015

[6] Innovate UK Production line readiness for high-value manufacturing

[7] Warwick Economics and Development. 2015. High value manufacturing catapult: Pathways to impact. https://hvm.catapult.org.uk/wp-content/uploads/2015/08/Impact-Evaluation-full-report.pdf

Assembly operations can be comprised of combinations of people and programmable robots/machines, supported via semi-automated sensing, actuation, fixing and tooling elements. The location of manufacturing operations is physically distributed (throughout a manufacturing site or over many sites) yet interconnected physically and logically; by semi-flexible computer controlled conveyors (sometimes distributed over several miles). 'Internal' logistic operations will be flexibly co-ordinated with those of 'external' (road, rail, sea and air) transport systems.

The businesses involved in networked assembly operations for parts and services throughout the supply chain will be located throughout the UK, Europe and globally. Connected technologies, with greater use of sensors and IoT data exchange networks will undoubtedly be the catalyst for further major advances in the globally competitive life cycle engineering and the disposal of future generations of goods and products.

During recent decades the dominant strategic thrust of product realisation paradigms within the automotive and other high value manufacturing sectors has been 'mass customisation'; because such an approach can provide dual economies of:-

- ***Scale*** - where large quantities of cars or goods are made efficiently using optimised systems of people and machine resources;
- ***Scope*** - where variants within models and/or between models are enabled by using common flexibly/computer controlled semi-automated resource systems that are also designed to operate efficiently in response to predicted variations in production demand.

For example the BMW Mini Plant in Cowley is achieving the combined economies of scope and scale production. It successfully creates mass customised cars at a factory heartbeat of 68 seconds (one vehicle is produced every 68 seconds; more than 1,200 per day) each of which individually meets distinctive customer specification - there are claimed to be more than a million possible customer options. Whilst the successful transformation of businesses is usually about more than just the adoption digital technologies[8] these technologies have the potential to be a catalyst for the future growth and success of manufacturing and the creation of new goods and business models.

Digital technologies transforming manufacturing

5G, other connected technologies and the Internet of Things will enhance active communication between sensors and devices. This is vital for inter-connecting manufacturing operations. Sensor technology is creating smaller and better devices that can communicate through the Internet or wirelessly without human intervention. Mobile communication and monitoring will provide real-time access to data and enable Enterprise Resource Planning systems to access real-time information from machines, sensors and workers. 3-D sensors, enhanced geo-location capability and wearable technology will improve communication between all machines and workers; whether they are located in the office, factory or off-site. Sensors will detect breakdowns and maintenance needs in real time, and use automated push alerts to schedule a response. Inventory management will enable tracking of raw materials, unfinished goods and final products with mobile devices and sensors from the moment they enter the factory to the moment they are sent to the customer[9]. Sensors and communication methods will include RFID, wearable technologies and other industrial and office sensors. These important technologies for the transformation of manufacturing are briefly considered below.

[8] Brynjolfson E and McAfee A. 2016. The second machine age. In addition to technology there usually has to be a smooth transition from legacy systems, buy-in and training for the workforce, re-organisation of operations, integration with other operations with the business and integration up and down the supply chain.

[9] Tech4i2, EY, IDC. 2014. Mobile business opportunities. https://ec.europa.eu/growth/tools-databases/dem/sites/default/files/page-files/mobility_v1.1.pdf

Radio-frequency identification (RFID)

RFID technology uses a combination of microchips, radio waves, and scanners to transform the way companies track things, especially inventory. By attaching the chips to objects, companies are better able to track everything from books to toasters to factory parts to pharmaceuticals[10].

IDTechEx estimate that 6.8 billion RFID tags were sold globally in 2014. They estimate the market in 2014 was worth £7.8 billion, increasing to £23.9 billion in 2024[11] (CAGR of 10.8 per cent). Study team estimates suggest the market in the UK could be worth between £120 and £260 million in 2014 and between £380 million and £800 million in 2024[12]. IDTechEx suggests sales will reach 125 billion tags in 2020 (this would require CAGR of 50.4 per cent). If this growth rate was achieved cumulative global sales of RFID tags could be approximately 380 billion in 2020. This could represent approximately 1,900 to 2,900 RFID tags per enterprise in the UK.

RFID chips are a digital extension of bar code labels. The advantage of these more “intelligent” systems is that, unlike barcode-based data collection, an RFID system can read the information on a tag without requiring line of sight or a particular orientation. This means that RFID systems can be largely automated, reducing the necessity of manual scanning.

Various types of tags and labels are available for use in different environmental conditions. Write Once-Read Many (WORM) or Read-only chips are pre-numbered and require a host database. Once a read-only RFID tag is programmed, the data cannot be altered for the life of the chip. These ‘passive’ chips can hold more information than a single bar code label. They have a range of 1 to 12 metres and generally cost somewhere between 5 and 15 pence.

Active chips represented only four per cent of total sales by volume in 2010, they can have a range of between 1 and 200 meters (depending upon wireless frequencies used) and usually cost £4 or more. Active chips hold more information and the information can be updated and changed as often as needed. An active chip becomes a portable database that travels with a raw material or product and allows companies to modify the data content throughout its journey along the supply chain. If desired, data can be permanently locked on a byte-by-byte basis.

RFID is the ideal technology for automating manufacturing and distribution data collection processes. And because it can provide a portable database that lives with the product throughout its entire lifecycle, it can be used to store product genealogy data, including any after market adjustments/up grades. Having the complete history attached to the product could assist in minimizing warranty risk and optimizing the efficiency of a possible recall[13].

RFID Journal has reported that companies in health care, manufacturing, retail and other sectors that have adopted RFID have been achieving outstanding gains in productivity[14]. By 2020 it is predicted that leading sectors utilising RFID will include retail, consumer goods, logistics and postal services alongside the current transport, security and safety applications[15].

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[10] Vickers M. 2016. Embedding RFID in the workplace. https://www.i4cp.com/trendwatchers/2006/08/25/embedding-rfid-in-the-workplace

[11] http://www.idtechex.com/research/reports/rfid-forecasts-players-and-opportunities-2014-2024-000368.asp

[12] Estimates calculated pro-rata the UK’s internet using population and Facebook using population as a proportion of global use of the two services in 2015.

[13] Intermec. 2007. Practical uses for RFID technology in manufacturing and distribution applications. http://www.danbygroup.com/uploads/docs/White_Paper_Practical_Uses_for_RFID_Mfg__Distribution.pdf

[14] Freda B. 2016. RFID and productivity growth: Behind the economic statistics. https://www.rfidjournal.com/purchase-access?type=Article&id=14905&r=%2Farticles%2Fview%3F14905

[15] Business Wire. 2016. Technavio Expects the Global RFID Readers Market to Exceed USD 7 Billion by 2020. http://www.businesswire.com/news/home/20160302005098/en/Technavio-Expects-Global-RFID-Readers-Market-Exceed

Wearable technology

Wearable technologies are clothing and accessories incorporating computer and advanced electronic technologies. One of the major features of wearable technology is its ability to connect to the Internet or a network, enabling data to be exchanged between a network and the device. Wearable devices such as activity trackers are a good example of the Internet of Things, since they are part of the network of physical objects or "things" embedded with electronics, software, sensors and connectivity to enable objects to exchange data with a manufacturer, operator and/or other connected devices, without requiring human intervention[16].

Accenture Technology Labs believe that growth in wearable displays (such as glasses) will be catalysed by companies, not consumers[17]. Forrester Research have stated that the market for company-provided wearables will be larger than the consumer market in the next five years[18]. CCS Insight estimated that 35 million wearable devices were in use at the end of 2014[19]. They estimated that cumulative global sales of wearables would reach 370 million in 2018. Study team estimates suggest the UK market could have between 6 and 12 million wearable devices in 2018[20]. CCS predict the global value of sales in 2016 will be £13.4 billion, they predict growth to £26 billion in 2020[21]. Study team estimates suggest the UK market could be worth between £210 and 450 million in 2014 and between £412 and 870 million in 2020[22].

Wearables can boost employee efficiency by providing real-time data access while freeing the wearer's hands to hold tools or equipment. Smart glasses can be used for hands-free instructional support, with text or schematics put into the wearer's view while they are carrying out a complex task. With smart glasses, Daimler assembly line workers view their checklists during their inspections, reducing the likelihood of missing an item or two because of a faulty memory. When a defect is discovered, inspectors can immediately make a voice-recorded report, photograph the problem with their glasses and forward their report and photos to workers to correct the errors[23]. Wearable displays can also enable a new level of video collaboration, for example, by connecting field workers or those on the shop floor with more experienced colleagues or management staff, who can then see exactly what the worker is seeing[24]. Goldsmiths University have found wearable technologies can boost employee productivity by 8.5 per cent and increase job satisfaction by 3.5 per cent[25].

Robotics

An industrial robot, as defined by ISO 8373, is a machine that consists of a series of segments, jointed or sliding relative to one another, for the purpose of grasping and/or moving objects. Traditional programmable robots are automatically controlled and reprogrammable to reproduce repetitious tasks. The new generation of robots are more dynamic and have the ability to perform intended tasks based on current state and sensing, without human intervention. A good example of

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[16] Wearable devices. 2016. What is wearable technology? http://www.wearabledevices.com/what-is-a-wearable-device/

[17] Accenture Technology. 2014. Putting werable displays to work in the enterprise http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Putting-Wearable-Displays-to-Work-in-the-Enterprise.pdf

[18] http://raconteur.net/technology/welcome-to-the-wearable-workplace

[19] http://www.ccsinsight.com/press/company-news/1944-smartwatches-and-smart-bands-dominate-fast-growing-wearables-market

[20] Estimates calculated pro-rata the UK's internet using population and Facebook using population as a proportion of global use of the two services in 2015.

[21] Lamkin P. 2016. Wearable Tech Market To Be Worth $34 Billion By 2020. http://www.forbes.com/sites/paullamkin /2016/02/17/wearable-tech-market-to-be-worth-34-billion-by-2020/#566c217e3fe3

[22] Estimates calculated pro-rata the UK's internet using population and Facebook using population as a proportion of global use of the two services in 2015.

[23] Rootstock. 2016. Wearables and manufacturing cloud ERP. http://www.rootstock.com/erp-blog/wearables-and-manufacturing-cloud-erp/

[24] ibid. Accenture Technology. 2014

[25] Chenneour C. 2016. Will wearables at work drive better corporate wellness? http://www.hrreview.co.uk/analysis/analysis-l-d/christine-chenneour-will-wearables-work-drive-better-corporate-wellness/61744

a new area for robotics is in picking and packing solutions where there are already scalable and expandable examples available at different levels of automation. Rover robotic handling systems, travelling at speeds in excess of 25 mph, can travel around workplaces, use sensors to pick or place items and utilise algorithms to make volumetric calculations about storing goods on shelves or packing mixed pallets. RoboticsBusinessReview.com report that the adoption of technology into supply chain logistics is poorly developed and growing volumes of world trade and eCommerce will catalyse the automation of logistics.

Global growth in robot installations were estimated to increase by 12 per cent CAGR between 2014 and 2017 reaching shipments of 288,000 in 2017. The worldwide operational stock of robots is expected to reach 1,940,000 in 2017. The US materials handling and logistics roadmap predict that by 2025, economical, high-speed automation to load and unload lorries should be available both at the carton and pallet level[26].

Energy and food sectors

As noted earlier accompanying sector reviews from this study have examined several of the 18 sub-sectors that comprise digital manufacturing. This section briefly reviews two of the larger sub-sectors to provide examples of how digital technological innovations could lead to major transformations and new business models.

Energy

One of the 18 sub-sectors categorised within digital manufacturing is energy. The deployment of smart meters and smart grids is expected to provide major benefits for consumers, energy businesses and the environment[27].

Most of the smart meters installed today use mobile phone-type signals to send meter readings to suppliers, and other wireless technologies to send information to in-home/premises displays[28]. The next generation of smart meters, which will be improved by enhanced connectivity (including 5G), will offer a range of 'more intelligent' functions, including real-time data exchange and better energy management. These new meters will better complement 'smart home' technologies.

Strategic benefits for energy suppliers of installing next generation smart meters with enhanced connectivity will arise from increased access to data and real-time information provision. This will support efficient energy generation, enabling savings in generation capacity, particularly during periods of high demand. When supply loads are shifted from peak to off-peak periods, electricity providers observe savings in short-term marginal costs due to lower generation costs. A UK government study found that the total strategic generation benefits that will arise from smart meters is more than £900 million[29]. The strategic benefit from the estimated 53 million smart meters in the UK in 2020[30] is forecast to be £17.50 per meter[31].

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[26] Bond M. 2014. The U.S. Roadmap for Material Handling & Logistics: Why 2025 matters today. http://www.mmh.com/article/the_u.s._ roadmap_for _material_handling_logistics_why_2025_matters_today

[27] Smart grids and meters. European Commission. https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters

[28] https://www.gov.uk/guidance/smart-meters-how-they-work

[29] Smart meter roll-out for domestic and small and medium non-domestic sectors (GB). Impact Assessment (IA). 30/1/2014. URN: 14D/033. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/276656/smart_meter_roll_out_for_the_domestic_and_small_and_medium_and_non_domestic_sectors.pdf

[30] Ofgem. Transition to smart meters. https://www.ofgem.gov.uk/gas/retail-market/metering/transition-smart-meters

[31] Calculations based on data from Smart meter roll-out for domestic and small and medium non-domestic sectors (GB). Impact Assessment (IA). 30/1/2014. URN: 14D/033. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/276656/smart_meter_roll_out_for_the_domestic_and_small_and_medium_and_non_domestic_sectors.pdf

The main operational benefits for energy suppliers will arise from data generated by smart meters. Smart meters with enhanced connectivity will allow energy providers to avoid frequent site visits for meter readings and safety inspections. More accurate 'real-time' data from smart meters should eliminate the requirements for utility companies to 'estimate' bills.

Increased use of smart meters is expected to enable customers to better understand their energy consumption by devices and activities (via IoT capabilities), allowing access to historical information and anonymised information about neighbour's habits. Households' access to this data is important in reducing energy consumption. A UK government study estimated that consumer benefits from decreased energy consumption facilitated by 5G are £4.8 billion per annum. This equates to approximately £90 per smart meter[32].

New business models could include 'energy-as-a-service'. This requires energy companies or new entrants to move from being energy providers (delivering energy to their clients) to becoming 'energy service providers' delivering packaged energy-efficient solutions to clients. For example consumers might have heating and cooling services provided by the 'energy company' rather than the consumer owning their own boiler and air-conditioner equipment. The consumer no longer pays for electricity or gas, but pays for the services of heating, cooling, use of a washing machine and fridge etc. A fundamental building-block for this new business model is the availability of reliable energy consumption profiles for different consumer types (e.g. actuarial data). This will allow energy service providers to correctly price their services to consumers based on accurate models and predictions of consumer energy usage.

Food

Technology has supported the evolution of a food delivery chain that is steadily becoming more complex, agile, dynamic, and multi-dimensional. Each link in the chain involves discreet and quickly evolving possibilities and needs[33]. Technology is providing new ways of working from using GPS in the field to ordering with tablets at the table.

Precision agriculture uses GPS tracking systems and satellite imagery to monitor crop yields, soil levels, and weather patterns to increase efficiency on the farm. Using these precision technology systems, farmers can pinpoint an exact location in a field to determine how productive the area is. Before, the entire field was treated as one unit, but now, farmers can find out which areas are more suitable for which crops so they don't waste seed, fertilizer, or pesticides[34].

Farms often span large areas and ***drones*** help to monitor the productivity of farmland. Drones are becoming a popular alternative to extra farm hands or satellites, and advanced technology is making drones more productive. With drones, farmers can locate precisely where a diseased or damaged plant is, more accurately release fertilizer and pesticides, or take photos and have immediate information about a certain area of the farm.

Sensors and the Internet of Things are becoming very important to food technology. The Internet of Things has already come to the farm in the forms of irrigation technologies and crop yield monitoring. Sensors can monitor soil conditions and other environmental factors using wireless sensors to reduce water waste. Sensors in grain bins allow farmers to monitor temperature and moisture levels remotely. Internet of Things devices are used to monitor insects and analyze data on crops remotely using GPS coordinates and wireless sensors. The base station targets specific destructive bug species, the tool has its own communication network between all the traps in fields and data can be uploaded to a network or the cloud.

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[32] Smart meter roll-out impact assessment. Ibid.

[33] Tryson L. 2015. How Technology is Changing, Challenging the Food Industry. http://www.foodqualityandsafety.com/article/how-technology-is-changing-challenging-the-food-industry/

[34] Gilpin L. 2014. Ten ways technology is changing our food. http://www.techrepublic.com/article/10-ways-technology-is-changing-our-food

3D food printing could disrupt some parts of the food industry. A commonly quoted 3D printed food is 3D Systems' candy, which is made of pure sugar with the ChefJet. They recently teamed up with Hershey's to print chocolate. NASA used a 3D printer to make a pizza and the Foodini is a 3D printer designed for the home kitchen. The user prepares the ingredients with a food processor or blender, and the 3D printer can print shapes using the blended mix.

In 2016 Wetherspoon launched a phone app to order and pay to have food and drinks delivered directly to user's tables. In New York the Breadcrumb app provides real-time views of tables, menus, lists of ingredients, processes sales and delivery tickets and sends orders to the kitchen[35].

Food retailers now reach around the world to optimize costs, as well as for wider varieties and substitutes for foods scarce on local shores. But globalisation has large implications for food safety, not least because exporting countries vary in safety standards. The safety challenges resulting from changes in food delivery are essentially the result of the broad trend toward faster, deeper technological innovation. Sensors and machines can now monitor and check food throughout the supply chain for contamination, temperature, humidity and tampering. This can eliminate complex and time consuming manual inspection[36].

Catalysts, disruptors and opportunities

Although slightly dated an extensive review and consultation about Technology Strategy Board and EPSRC manufacturing strategies undertaken in 2011 was used as an evidence base to underpin the '*High Value Manufacturing Strategy 2012 to 2015'* published by the Technology Strategy Board in 2012[37]. The strategy emphasised the need to 'turn scientific excellence into economic impact by delivering results through innovation' and 'accelerating UK economic growth by nurturing high-growth potential SMEs in key market sectors'.

The strategy identified five 'critical cross cutting strategic themes' and existing national competencies. These included:-

> ***Resource efficiency:*** Securing UK manufacturing technology against energy and resource scarcity. Existing national competences included - Energy generation and storage; Management and security; Design and manufacture for sustainability and through life; Biotech, biological and synthetic biology processing; Design and manufacture for lightweight vehicles, structures and devices;
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> ***Manufacturing systems:*** New systems can increase the global competitiveness of UK manufacturing technologies by supporting more efficient and effective manufacturing. Existing national competences included - Understanding designing and manufacturing formulated products; 'Plug and play' manufacturing; Design and manufacture for small-scale and miniaturisation; Process engineering capability and efficiency across food, pharmaceuticals and chemicals; Novel mechanical conversion processes for scale economy and efficiency; Systems modelling and integrated design/simulation; Automation, mechanisation and human/machine interface;
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> ***Materials integration:*** Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies. Existing national competences included - Smart, hybrid and multiple materials; Intelligent systems and embedded electronics; Development and application of advanced coatings;

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[35] Pullen J. 2012. Five technologies changing the restaurant industry. https://www.entrepreneur.com/article/224332
[36] Tryson L. 2015. Ibid
[37] Technology Strategy Board. High Value Manufacturing. 2012 to 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/362294/High_Value_Manufacturing_Strategy_2012-15.pdf

Manufacturing processes: Developing new, agile, more cost-effective manufacturing processes. Existing national competences included - Flexible and adaptive manufacturing; Combining product development steps in parallel/ concurrent engineering; Additive manufacture; Net and near net shape manufacture;

Business models: Building new business models to realise superior value systems. Existing national competences included - Managing fragmented value chains, including distributed manufacturing to support digital manufacturing; Building new business models to support digital manufacturing; Developing and retaining skills to support digital manufacturing; Managing risk and resilience to support digital manufacturing.

The most promising process and service advances forecast for growth in the Technology Strategy Board strategy included:-

Additive manufacturing	Bioprocessing for new/replacement materials/fuels
Customisation	End of life activities: recycling, re-use, and renewing
Enhanced robotics and automation	ICT and enabling ICT structures
Integrating technologies and processes	Link design and manufacturing more closely
Net shape manufacturing	Small run technologies (e.g. ‘batch size of one’)
Surface engineering (finishing and coating processes)	

Disruptors identified by the Technology Strategy Board strategy included:-

- Increasing costs of energy; particularly exploiting the low carbon market; reducing usage of and securing materials;
- Building necessary skills and attracting them to manufacturing;
- Influencing the evolution of government economic, taxation and regulatory policies and ensuring the ability to adapt, exploit and conform as these policies evolve;
- Bridging the innovation gap/’valley of death’;
- Creating new business models to exploit innovation and capture value.

In addition to investigating separately the four technologies (connected, data driven, immersive and intelligent) and four sectors (creative, digital manufacturing, healthcare and wellbeing and transport) that provide the focus for research the study team also undertook a brainstorming exercise with catapult staff. Discussion focused on opportunities for cross-fertilisation (within and between technologies and sectors) and the identification of commercial opportunities.

A key area that presents big opportunities within the digital manufacturing sector is related to one of the key themes that is present throughout the strategy, technology and sector overviews presented in this paper - the amount of information and data that can now be generated throughout the supply chain and workplace.

Logistics is an area where better access and coordination of data about moving objects (parts, goods, pallets, vehicles) could considerably increase logistical efficiency. Vast numbers of logistic chains across all sectors supply, produce, store and deliver physical and logical (data/digital) objects throughout the UK and abroad.

Integrating supply and logistics activities both within and beyond organisational boundaries has become and will continue to be a major challenge for digital manufacturing businesses. Integration efforts now extend beyond traditional product-process design and functional integration to focus on extra-organisational links with customers and suppliers. There is a growing need to better coordinate and utilise the increasing amounts of information that can be generated and utilised to assist the future growth and success of digital manufacturing[38].

[38] Carter P et al. 2009. Supply Chain Integration: Challenges and Good Practices. http://www.som.cranfield.ac.uk/som/dinamic-content/media/research/scrip/capsreport.pdf

Many well-known examples of bespoke supply chain innovations, such as those introduced by Amazon and BMW, have transformed business operations. Significant opportunities were identified for development of more generic scalable data collection, analysis and sharing systems concerning supply chains. Indeed the complex (multi-partner, multi-customer, multi process and service, geographically distributed and highly dynamic) nature of such chains offers enormous emergent business opportunity[39]. But exploitation of the opportunity requires the intervention of a respected partner, such as the Digital Catapult, to develop scalable systems or demonstrators with committed partners in digital manufacturing sectors.

[39] Weston R and Cui Z. 2011. Enterprise and simulation modelling in architecture execution. International Journal of Industrial and Systems Engineering.