

MSc Industry 4.0 Advanced Manufacturing

Master's Dissertation

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Industry 4.0 Technology – Is it the solution for UK Manufacturing?

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Executive Summary

Technological change is happening rapidly. The pace and scope of scientific and technological advances from research facilities, start ups and large organisations is providing us with new capabilities. It has been said that the technologies driving the fourth industrial revolution will transform the world economy. Every company in every industry must change the way they operate to keep up with the rapidly changing technology and realise the benefits they can deliver. (Schwab, 2017)

This study explores these new, innovative Industry 4.0 technologies and whether they are adopted by UK Manufacturing, and whether the UK is keeping up with other developing countries in technological adoption.

There is a vast variety of Industry 4.0 technologies to research to validate adoption of Industry 4.0. in the UK. This dissertation explores Low Power Wide Area Network (LPWAN) technology for a more focussed outlook.

Larger companies, such as Audi, publicise their 'Smart Factories,' celebrating the Industry 4.0 revolution and the benefits they provide. Larger companies that utilise technologies such as Cyber Physical Systems, Industrial Internet of Things, Cloud Manufacturing and Artificial Intelligence invest resources to fund, develop and implement these technologies to improve business/manufacturing or service performance. UK manufacturers, including SMEs may not have the resources to implement these technologies and would have to implement them on a smaller scale.

Challenges that slow the integration of Industry 4.0 are explored, comparing developed countries commitment to Industry 4.0 to the UK's. Government strategy and policies across the world and in the UK are discussed, with China and India among others that have committed national policies which incorporate Industry 4.0 technology.

Knowledge and awareness are focal points of research, to determine end user, technology suppliers and industry expert's understanding of Industry 4.0.

These Economic, Social and Political factors may inhibit Industry in the UK. This research study is undertaken to determine if these challenges are slowing UK Industry 4.0 adoption, or whether it is the solution.

About the Author

The author has been in the field of engineering for 27 years, experiencing engineering, automation, and industrial processes. Having worked for over twelve different companies a good understanding of how industrial sectors differ, and what common themes span those sectors has been developed. Starting out as an apprentice electrical engineer, to the Head of Engineering, this career has developed a wide outlook on the engineering and manufacturing environments.

Industry 4.0 awareness was not prevalent until the MADE Cymru educational partnership programme sought out the author to provide the awareness that the UK manufacturing community is in requirement of.

Personal experience of projects and technology upgrades, some of which are Industry 4.0 has given the author a basic level of Industry 4.0 practical experience, which may be referenced in this research study.

Table of Contents

Executive Summary

1. Chapter 1 – Introduction

- 1.1. Research Background and Justification
- 1.2. Research Aims and Objectives
- 1.3. Research Methodology

2. Chapter 2 – Industry 4.0

- 2.1. Industry 4.0 Technology Overview
- 2.2. Industry 4.0 Technology in UK Manufacturing
- 2.3. Industry 4.0 Summary

3. Chapter 3 – Low Power Wide Area Networks (LPWAN)

- 3.1. LPWAN Technology Overview
- 3.2. LPWAN Technology in the UK
- 3.3. LPWAN Summary

4. Chapter 4 – Industry 4.0 and LPWAN – Industrial Professionals

- 4.1. Research Interviews – Industrial Service Providers
- 4.2. Interview – Industrial Service Providers Discussion
- 4.3. Interview – Industrial Service Providers Conclusion

5. Chapter 5 – Industry 4.0 and LPWAN Adoption in UK Manufacturing

- 5.1. Research – End User Surveys
- 5.2. End User Survey Discussion
- 5.3. End User Survey Conclusion

6. Chapter 6 – Practical Case Study

- 6.1. Case Study – Fillcare Ltd – Predictive Maintenance (Pd.M.) pilot
- 6.2. Case Study Discussion
- 6.3. Case Study Conclusion

7. Chapter 7 – Discussion

- 7.1. Introduction
- 7.2. Research Findings

8. Chapter 8 - Conclusion

- 8.1. Conclusion
- 8.2. Recommendations
- 8.3. Limitations

9. References

10. Appendix

- 10.1. Appendix A – Research Interviews – Industrial Service Providers
- 10.2. Appendix B – Research – End User Survey

1. Chapter 1 – Introduction

1.1. Research Background and Justification

Technology is constantly evolving, developing, and offering innovative solutions, benefits, and improvements to businesses. Industry 4.0 encompasses the innovative technologies that are being developed at a rapid pace.

Large Multinational Companies, such as Audi, are utilising such technologies to gain the benefits of this revolution, developing Smart Factories to maximise the Industry 4.0 innovations. Recently reducing labour costs by 30% after introducing Artificial Intelligence (A.I.) quality inspection systems, partnered with Intel. (*Intel Corporation, 2023*)

Significant investment is required to implement these innovative improvements partnerships. For large Multinational companies this investment is available, to achieve the significant return on investment. (*Intel Corporation, 2023*)

For smaller companies, with lower disposable finances, the Smart Factory solutions are out of reach. Businesses with less complex manufacturing processes may not need such radical technology Innovations. Industry 4.0 however, can be implemented on a smaller scale, albeit smaller benefits. These areas of improvement should be explored by Small, Medium Enterprises (SMEs) or large businesses with less disposable income.

Industry 4.0 technology can deliver improvements to all areas of a business. An understanding of the capability to adopt new technology, or an appetite to innovate is important to determine how well the benefits of Industry 4.0 is being delivered in Manufacturing businesses. Businesses may not be aware of the improvements available, or the resources to implement the technology, or simply that the technology is not relevant to the Manufacturing process. This study will assist to determine these factors and bring recommendations to further understand and how to overcome them.

1.2. Research Aims and Objective

This research is focussed on Industry 4.0 technologies that have emerged in recent years. Major advancements in technology in a relatively short space of time has resulted in the term Industry 4.0, signifying that there is an Industrial Revolution in progress. (*Schwab, 2017*) This research reviews the types of Industry 4.0 and how accessible it is to manufacturing companies.

A key point for review is the adoption of Industry 4.0 technologies. With a vast array of technologies, Low Power Wide Area Networks (LPWAN) will be a focal point of the research. This will enable a more critical review of its technology, costs, benefits, and adoption in manufacturing business.

This study aims to identify the awareness, knowledge and understanding of LPWAN technology with reference to Manufacturing Industry Suppliers and Users. Research into Economic, Social and Political factors will be used to understand the appetite for adoption, and what factors make Manufacturing companies reluctant to introduce Innovation in the form of Industry 4.0 technology.

An objective of the research is to determine if there are gaps in adoption, and if so, how to close the gap. The goal is to develop recommendations to enhance the technology engagement, so Manufacturing companies can gain the benefits of LPWAN, and Industry 4.0.

1.3. Research Methodology

Research will be carried out with a Mixed Method to gather the necessary data and information to fulfil the objectives. A wide range of resources will be used to confirm accuracy and credibility of research, which will result in accurate and credible conclusions in this study.

Qualitative

- Literature Reviews of Case studies, journals, reports and websites will be conducted, to determine awareness, knowledge, and implementation of Industry 4.0 and LPWAN technology.
- Interviews will be conducted with technology suppliers and industry experts to understand the awareness and implementation of Industry 4.0 and LPWAN.

Quantative

- Literature Reviews of case studies, reports and websites will be used to extract statistical data to quantify awareness, implementation and market share of the technology.
- Surveys will be distributed to Manufacturing engineering End Users to provide statistics to evaluate awareness, knowledge and experience of Industry 4.0 and LPWAN technology in UK Manufacturing.

Trial

- An LPWAN technology application will be trialled to determine difficulty to source devices, knowledge to install, and ongoing use of the technology.

2. Chapter 2 – Industry 4.0

2.1. Industry 4.0 Technology Overview

Industry 4.0 refers to the 4th Industrial Revolution. “The word ‘revolution’ denotes an abrupt and radical change. Revolutions have occurred throughout history when new technologies and novel ways of perceiving the world triggers a profound change in economic systems and social structures”. (Schwab, 2017a)

Four Industrial Revolutions

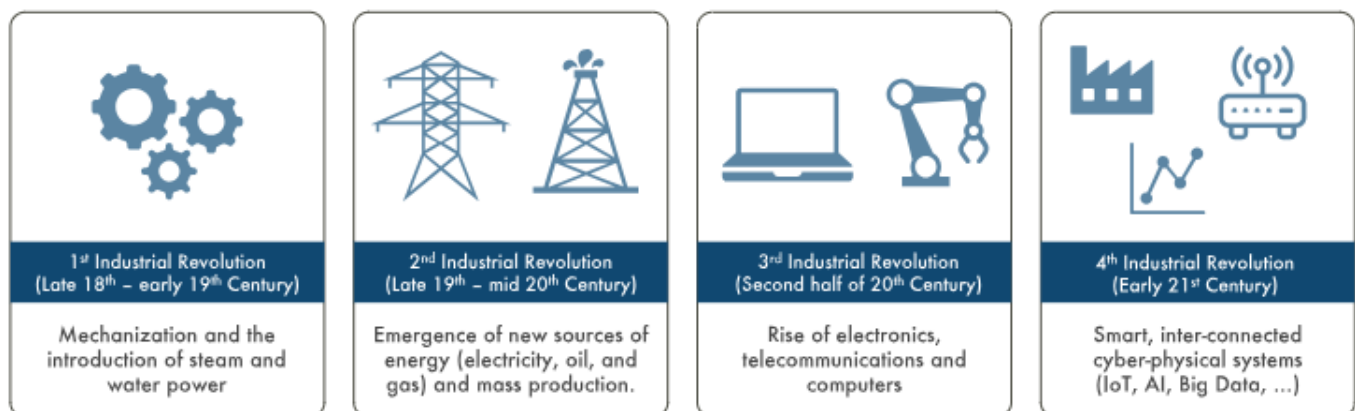


Figure 1. The four Industrial Revolutions (The MathWorks Inc., 2021)

- The first industrial Revolution (1760s -1850s) resulted from the invention of the Steam Engine. The mechanisation of machinery boosted industry, enabling larger and more productive manufacturing processes.
- The second industrial Revolution (1870s -1910s) sparked from the developments in electricity. Steam powered machines were replaced by electrically powered machinery enabling the introduction of the mass production line.
- The third industrial Revolution (1950s -1980s) arose from the invention of the Integrated Circuit. Computer and telecommunication technology enabled by Integrated Circuits introduced machinery automation.

Industry 4.0, or the fourth industrial revolution, is the advanced automation of traditional manufacturing and industrial processes using technologies such as Industrial IoT (Internet of Things), Big Data analytics, Artificial Intelligence (A.I.), Robotics, and Autonomous systems. These technologies can be used to increase manufacturing capability, productivity, and efficiency. It also enables flexible, customer-centric production and reduces operational and maintenance costs. (The MathWorks Inc., 2021)

The term Industrie 4.0 was invented by three engineers – Hennin Kagermann (founder of SAP), Wolfgang Wahlster, and Wolf Dieter Lukas. It was referenced in the Hannover Messe (Fair) in 2011 in an article regarding the German government high tech strategy for 2020. (Accialini Nicola, 2021) It is a term that was used to describe how the organisation of global value chains would be revolutionised. By enabling Smart Factories Industry 4.0 can create a world where virtual

and physical systems can cooperate in a flexible way. This enables new operating models and customization of products.

It is not only about Smart machines and systems. It incorporates new Innovations such as nanotechnology, renewables and quantum computing to interact and make Systematic change in the digital, physical and biological environments. From Smart Factories to Renewable energy, to ordering a taxi, Industry 4.0 technology operates within all aspects of the modern world. *(Schwab, 2017a)*

This quote by Pereira seems an efficient summary of the major technologies: “This emerging Industry 4.0 concept is an umbrella term for a new industrial paradigm that embraces a set of future industrial developments regarding Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS), Robotics, Big Data, Cloud Manufacturing and Augmented Reality”. *(Pereira, 2017)*

Cyber Physical Systems

Cyber Physical Systems (CPS) refer to systems that are integrations of computational technology, networking and physical processes. Digital technologies communicate data across networks to computerised systems which make logical decisions and communicates data to physical technologies that carry out instructions. The physical technology or process is analysed and fed back to the computerised system. Examples would be Autonomous vehicles, such as Driverless trains and Driverless cars that utilise advanced programming, technology and intelligent feedback to autonomously control the physical operation of the vehicles. An absolute example would be a Smart Factory – relying on autonomous systems to control process throughout the factory. *(Gilchrist, 2016)*

Internet of Things (IoT)

The Internet of Things (IoT) refers to devices and ‘things’ that are connected to the internet with the ability to interconnect and communicate data. Embedded technology monitor and control these devices remotely utilising the inputs and outputs to these devices to control processes. Examples are Smartphones and Smart Energy metering devices, such as wireless electricity meters, or wireless temperature sensors, that can be deployed easily, with low cost to enable data capture across networks. Industry 4.0 network protocols are required to process the wide range of devices. Network types include Low Power Wide Area Networks (LPWAN) that can reach IoT devices from wide ranges, using low power are employed to help process the wide range of devices. Cyber Physical Systems use the IoT to gather data, communicate and control physical devices used in the process required. *(Soldatos et Al., 2019)*

A simple example would be a Yale Smart Lock. The Smart Lock uses Bluetooth technology and wi-fi to connect to the internet, or home network to perform as a Smart device. The lock can be unlocked remotely, transmit data to notify user of operation, and even alter authorisation of wireless entry with the control via Smartphone Application. *(Assa Abloy)*



Figure 2. Yale Smart lock (Assa Abloy)

A more advanced example would be LoRaWAN Vibration sensors, used to monitor vibration on motors and pumps as part of Condition Monitoring networks.

LoRaWAN wireless vibration sensors can measure both vibration and temperature data. The sensor combines a uniaxial or triaxial accelerometer, a data collector, and a radio into one compact, battery-operated device. With a long range for data transmission inaccessible areas can use these sensors without the cost of wired in networks. *(TE Connectivity, 2024)*



Figure 3. Vibration sensor (TE Connectivity, 2024)

Internet of Services (IoS)

Internet of Things (IoT) is supporting the Internet of Services (IoS). The technology and data available are enabling service orientated solutions such as smart homes, smart offices, and smart cities. IoS would include cloud platforms,

technology solutions where the user would be provided access, instruction, and ongoing support for a product. (Sadiku et al., 2018) An example would be the Yale Smart Lock partnering with Zipato to deliver a home security system. Zipato is an automation platform that provides applications for PC or smartphone that Yale uses to control Smart devices such as the Yale Smart Lock. (Zipato, 2020)

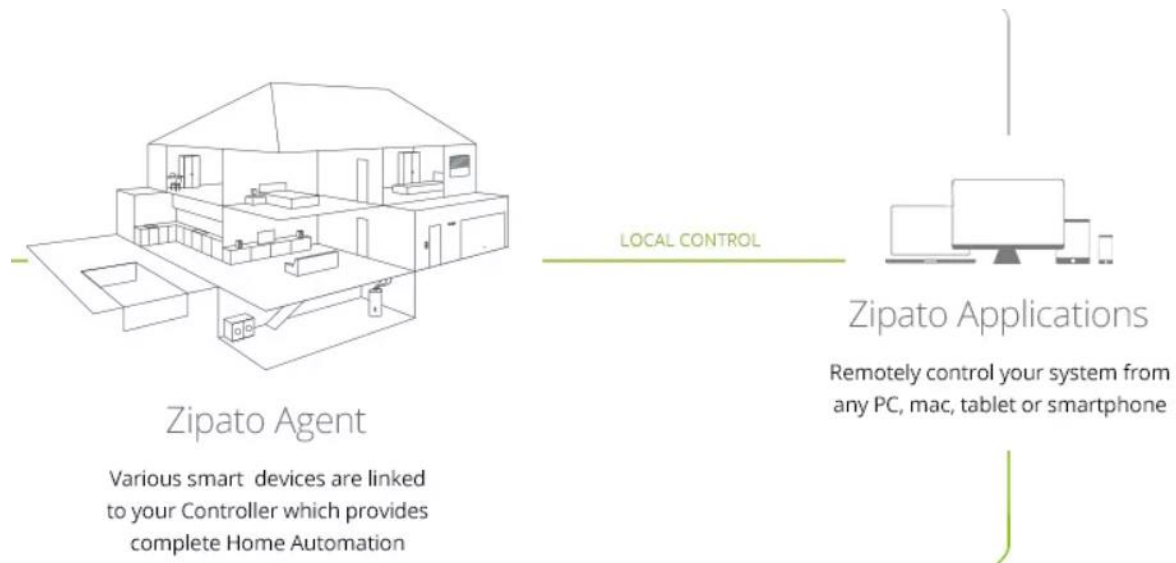


Figure 4. Smart home application (Zipato, 2020)

Robotics

Robots are commonly used, often reliant on Human programmed control. Industry 4.0 refers to robotics functions that are more adaptive and autonomous by using network connections and Cloud based control systems. Robots can communicate with other systems and have their function altered remotely whenever necessary. Robots would include Collaborative Robots, Automated Guided Vehicles and Drones. (Accialini Nicola, 2021) An example would be Amazon Prime Air. Amazon use Drones to autonomously deliver packages to customers in various locations across the U.S.A. (Chen, 2023)



Figure 5. Amazon Air drone- MK30. (Chen, 2023)

Big Data

Technological development has introduced smaller sensing devices and faster communications networks. These advances have allowed a larger number of more sophisticated sensors to collect substantial amounts of data. This data, along with data sources such as videos, HTML, GPS data are collectively termed as Big Data. The large quantity of data can be transmitted simultaneously, processed, and potentially stored. The revolution in communication networks, cloud server storage and processing power has allowed Big Data to exist. *(Gilchrist, 2016)*

Cloud Computing Services / Cloud Manufacturing

The advances in IoT and IoS has produced 'Cloud Manufacturing.' Cloud Manufacturing is based on the software systems and platforms of a business being ran from a Cloud Based service provider. Platform providers use data centres to store software and databases. The customer accesses the servers via the Internet, removing the in-house physical server requirement. Cloud services providers such as Amazon Web Services (AWS) offer Infrastructure as a Service (IaaS) and Software as a Service (SaaS) to enable the reduction of data storage and processing by the customer, which can lead to cost reductions, better efficiency and security. *(Gilchrist, 2016) (Amazon Web Services, 2024)*

An example of this is Autodesk partnering with AWS (Amazon Web Services) to use AWS services, data centre, and expertise, as below:

"When Autodesk launched in 1982, its desktop software helped transform the architecture, construction, engineering, manufacturing, media and entertainment industries. The company has continued to innovate in the decades since, now offering subscription software services to more than one hundred million customers worldwide. To meet this exponential growth in customers and data, Autodesk migrated workloads from its on-premises data centres to Amazon Web Services (AWS) in 2012, taking a hybrid cloud approach. As a result, Autodesk has increased efficiency, scalability, and flexibility and enhanced reliability, security, and analytics capabilities—while saving up to 90 percent on data processing costs. Freed from manual processes, Autodesk's data scientists can now focus on further innovation, using big data, machine learning, and serverless solutions on AWS". *(Amazon Web Services, 2024)*

Generative Design

Cloud Computing Services and Artificial Intelligence (A.I.) has enabled Autodesk to develop Fusion 360. Autodesk Fusion 360 is a design, engineering, electronics, and manufacturing software. It is a cloud-based software with integrated 3D CAD, CAM, CAE, and PCB capabilities. It involves a high degree of processing power, which has been enabled by Cloud computing. A function it is commonly used for is Generative Design. *(Autodesk, 2024)*

Generative Design is a form of A.I. that automates the design process. It is commonly used with CAD for product and building design, although branching out in other applications, such as artwork. It is used to create and optimise a design that meets certain factors which may not be capable with human design capabilities. *(Autodesk, 2024)*

Honda R&D used Generative Design to produce a Crankshaft weighing 50% lighter *(Figure 6)*. An initiative to reduce the Carbon Footprint of Transport by reducing the weight of components led Honda to use Generative Design and Additive Manufacturing to produce this lighter component. *(Matsunaka, 2022)*



Figure 6. A rendering of the generative design crankshaft model. (Matsunaka, 2022)

Additive Manufacturing

Additive Manufacturing uses data computer-aided-design (CAD) software to instruct ‘printers’ to deposit material, layer by layer, in precise geometric shapes. Additive manufacturing adds material to create an object, whereas traditional manufacturing methods are subtractive, removing material through processes such as milling and carving. Printing can refer to methods including depositing of melted material, laser melting of powders or Ultraviolet curing of materials. Complex geometric designs can be produced with this technology, that could not be achieved by traditional processes, enabling lighter designs and rapid prototyping that traditional processes could not achieve. This provides the opportunity for Mass customisation, tailoring products to customer requirements. (*General Electric., 2023*)

Honda's crankshaft example is below:



Figure 7. The metal-printed prototype for the generative-design crankshaft model. (Matsunaka, 2022)

Predictive Maintenance (Pd.M.)

Industrial organisations are employing Predictive Maintenance to improve the reliability of machinery and equipment. It is based on collection of data such as vibration, temperature, ultrasonic and power consumption to determine the condition of the equipment. Big Data capability and Artificial Intelligence allows the predictive condition-based monitoring system to forecast maintenance more efficiently than planned preventative maintenance, as the actual condition dictates what is required and when. (Soldatos et Al., 2019)

Smart Factory

In 2021 Audi launched an initiative for a digital factory transformation in Neckarsulm. The goal was to establish a world leading digital factory transformation. The initiative was a collaboration between Audi, TU Munich, Fraunhofer IAO, XL2, Capgemini, AWS, and SAP. Audi Board Member for Production Kössler: “Together with our ‘Automotive Initiative 2025’ partners, we will develop the Neckarsulm site into a leading factory for digital production and logistics within the Group. (Audi Mediainfo, 2021)

Audi already uses digital solutions at its manufacturing sites and aim to develop the Neckarsulm site into a leading factory for digital production within the group.

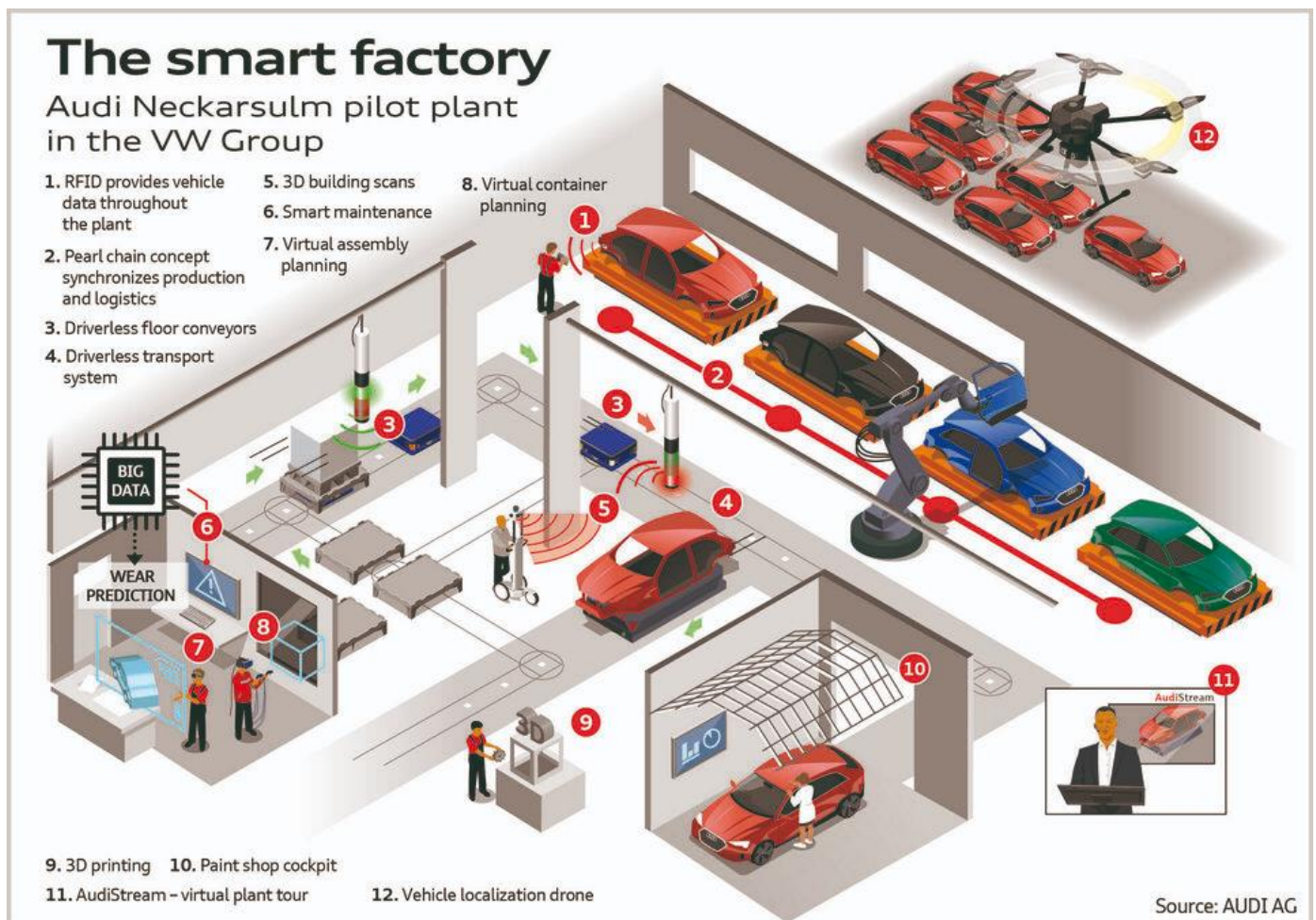


Figure 8. The Smart Factory (Audi Mediainfo, 2021)

Industry 4.0 Technology used in the Audi Smart Factory (*Figure 8*)

1. RFID provides vehicle data throughout the plant – RFID allows each vehicle to be identified individually throughout the process.
2. Pearl Chain concept – An algorithm can process two trillion possibilities to determine the ideal sequence of cars on the assembly line to optimise workload.
3. Driverless floor conveyors – automated transport
4. Driverless transport systems – a digital map using RFID, laser scanners and wheel movements allow cars to navigate through the factory.
5. 3D Building scans – 3D Scans create a virtual image of the facility, allowing production planning regardless of location.
6. Smart Maintenance – IoT and Big data analysis calculates condition, predicting when maintenance is required.
7. Virtual Assembly planning - 3D scans and machine learning allows testing of assembly processes without physical prototypes – digital twin.
8. Virtual container planning – Containers for transporting and storing are also virtually planned.
9. 3D Printing – 3D printed assembly aids are produced quickly and accurately. Software reduces design times by 80%.
10. Paint shop cockpit – Data from the paint process is processed to identify deviations.
11. Audistream – virtual plant tour – anyone can experience the plant up close from anywhere using the virtual tour.
12. Vehicle localisation drone – autonomous drones use RFID and GPS to detect and store exact positions of vehicles. (*Audi Mediainfo, 2021*)

This is the vision of Industry 4.0 but noting that a collaboration of leaders in industrial technology is pioneering the digital factory transformation. Multi-national companies such as Audi have the resources to implement innovative technology and gain the associated benefits.

2.2. Industry 4.0 Technology in UK Manufacturing

The UK was the 8th largest manufacturing economy by value of output in 2023, totalling £224 billion, providing 2.6m jobs in the UK, and accounted for 10% of UK GDP. (*MakeUK, 2024b*)

In 2022 the UK Tech Sector was Europe's leading tech ecosystem, raising £24 billion and employing over 3 million people in the UK tech industry, enabling the UK to produce almost 400 high-growth startups since 2000. (*Gov.uk, 2022*) Also in 2022 the digital infrastructure of the UK delivered 97% superfast broadband coverage, and 92% of UK landmass was covered by a good 4G Signal. (*Gov.UK, 2022b*)

The United Kingdom is ranked 6th as one of the Most Technologically Advanced Countries 2024. Countries were ranked by a composite score based on internet and 4G users as a percentage of the population, a digital competitiveness score and investment on research and development. (*World Population Review, 2024*)

The value of manufacturing to the UK economy is high and the UK has high technological attributes. This would suggest

Page | 14

that the UK would be at the forefront of Industry 4.0 implementation and development. However, there is a concern that the UK is behind in adopting Industry 4.0 technology, in forms of Industrial Digital Technologies (IDTs) and Automation. A study carried out by EY in 2022 shared that of those surveyed only 11% of large organisations were at the 'advanced' stage of digitisation. (*Chalmers, 2023*) The Make UK and PwC Executive Survey 2024 states that only 23% of manufacturers in the survey see opportunities in digital technologies and only 12.5% are making digital technology central to their strategies in 2024. (*MakeUK, 2024b*) Another Make UK report states that despite the UK manufacturing sector being the 8th largest in the world the country only ranks 24th globally for robotic density, with an average of 111 robots per 10,000 employees. (*MakeUK, 2024a*) According to an RSM article approximately 50% of UK companies are actively working on Industry 4.0, UK productivity is languishing behind other nations and the faster the UK adopts Industry 4.0 the quicker it will address its productivity gap. (*RSM International Ltd, 2024*).

Industry 4.0 – Challenges

Costs

The Make UK and PwC Executive Survey 2024 states 21% of manufacturers in the survey expect to see profit margins decline in 2024, and 16% expect a reduction in cash flow. (*MakeUK, 2024b*)

Many factories have a mix of newer and decades-old equipment that lacks the sensors and internet connectivity crucial to a smart factory. It would require large investment to make IoT systems compatible with older manufacturing systems, which may use different technology standards. Manufacturers also cite deployment costs and difficulty gaining management buy-in as further obstacles of an Industry 4.0 approach. (*Ricadela, 2023*) SMEs struggle to justify the cost of new tech solutions, especially when adopting technology which would require changing other business processes to enable its use. (*Be The Business & McKinsey, 2020*)

With available finances expected to be lower in 2024, the lack of awareness for the economic benefits of Industry 4.0 could reduce its adoption with other initiatives prioritised.

Lack of expertise and execution support

Lack of technical knowledge and skilled employees hinders the deployment of Industry 4.0. Larger businesses may have access to greater support and have specialists with the skills to implement and lead the introduction of new systems whereas SMEs may not have this expertise. (*Be The Business & McKinsey, 2020*)

A lack of technical skills hinders plans to automate and invest in new technology and manufacturers do not understand what digital tools are available, with studies surmising that lack of resources and lack of employee's expertise being the most dominant barrier to Industry 4.0 adoption. (*Shashank Kumar, et Al 2022*)

The Role of the Government

Governments need to understand the potential provided by these technological advances. They need to adopt these technologies and promote and support widespread development. (*Schwab, 2017b*)

Government support is a crucial driver of Industry 4.0 adoption. Such support may include promotion and awareness programmes, resource allocation, financial assistance, tax incentives, IT infrastructure development and high-speed Internet connectivity. (Mohuiddin, 2023)

MakeUK released a report in February 2024 delving into UK manufacturing - 'Beyond Ambition: Advanced Manufacturing' which states that "A lack of a proper, planned, industrial strategy is the UK's Achilles heel. Every other major economy, from Germany to China, to the US, has a long-term national manufacturing plan, underlying the importance of an industrial base to the success of its wider economy. The UK is the only country to not have one." (MakeUK, 2024a)

In 2020 a report by the University of Cambridge highlighted differences between the UK approach and that of other countries:

Technology diffusion – other countries' Industry 4.0 initiatives put emphasis on diffusion of technologies. Germany put emphasis on supporting SMEs to become more aware of Industry 4.0 providing them with information, training and providing learning factories for companies to test technologies with industry experts. Korea launched a Ministry for SMEs and Startups to focus on SME and digital manufacturing. (Jennifer Castaneda-Navarrete, 2021)

Programme scale/coverage - Countries such as Germany, Taiwan and Korea have national Industry 4.0 mandates and the US supports Industry 4.0 with the Manufacturing Extension Partnership. The UK approach was to establish a regional pilot in the Northwest region with the Made Smarter Programme. (Jennifer Castaneda-Navarrete, 2021)

Emphasis on training – Korea and Singapore use demonstration facilities to deliver Industry 4.0 courses, with Singapore creating the Skills Future Series for Advanced Manufacturing which provides training to accelerate Industry 4.0. In the US Digital Manufacturing Jobs are identified that will be transformed by digital technology. (Jennifer Castaneda-Navarrete, 2021)

The UK has developed the 'Made Smarter' Initiative which is the UK's main national Industry 4.0 programme. The main work streams were the Northwest Made Smarter Adoption pilot programme to help 3000 manufacturing SMEs in Northwest England adopt digital technologies; and the Manufacturing Made Smarter Challenge programme which invests in digital R&D and adoption of new digital technologies. (Jennifer Castaneda-Navarrete, 2021)

Industry 4.0 in the UK - Solutions

In 2017 the UK Government recognised that the UK had challenges with regards to the adoption of Industrial Digital Technology (IDT). They commissioned Professor Juergen Maier to put forward proposals to transform UK manufacturing through the adoption of IDT. This independent report was the 'Made Smarter Review 2017', which focussed on three priority areas – Leadership, Adoption, and Innovation. (Gov.UK, 2017) The review received an active contribution from more than 200 organisations, resulting in recommendations that can achieve the UK's ambition of becoming a world leader in the Fourth Industrial Revolution by 2030.

The review considers the benefits of IDTs on UK Manufacturing and discusses case studies of businesses that have benefited from the new digital technologies. It estimates that digital technologies could contribute £454 billion over the next decade. (Maier, 2017) The review identifies three key themes that are preventing the UK becoming a leader in IDT – Adoption, Innovation and Leadership.

Adoption barriers include limited support structure, no recognised independent source of advice, SMEs see investment in technology as a risk, SMEs do not have the capacity to partner with research organisations, limited access to state-of-the-art research, skills shortages and legacy infrastructure due to low levels of investment. (Maier, 2017)

Innovation is uncoordinated, with a lack of help for researchers to engage with industry to ensure they develop solutions to real-world challenges. More research institutions are required to advance skills development, provide expert advice, and give access to specialist equipment. (Maier, 2017)

Regarding leadership it is recognised that there are centres of technical expertise, but are fragmented with no coordination to provide focus for each technology. There is no UK national strategy and no model for business engagement, comparing to other developed countries who have national campaigns for industrial digitisation. (Maier, 2017)

The Made Smarter Review 2017 has identified three recommendations to resolve the issues. These are:

1. Create a more visible and effective ecosystem that will accelerate the innovation and diffusion of IDT.
 - Establish a new National Adoption Programme.
 - Create a network of Digital Innovation Hubs.
 - Implement large-scale Digital Transformational Demonstrator programmes.
 - Make the UK a global leader in IDT R&D.
2. Upskill a million industrial workers to enable digital technologies to be deployed and successfully exploited.
 - Increase investment and uptake in skills acquisition.
 - Better identify future skills requirements.
 - Improve the provision of and access to quality training.
 - Create an agile skills development system.
 - Create a culture of lifelong learning and more visible career pathways for adults.
3. Inspire the UK's next industrial revolution with stronger leadership and branding of the Country's ambition to be a global pioneer in IDTs.
 - Increase the number of manufacturing SMEs accessing support from Growth Hubs.
 - Increase the number of manufacturing SMEs using research, innovation, and catapult centres.
 - Increase the adoption of digital technologies, especially among smaller enterprises.
 - Raise the profile of UK manufacturing and engineering.
 - Raise awareness of the UK brand and approach with international investors and collaborators.

(Maier, 2017)

These recommendations will be supported by the Made Smarter Commission UK (MSUK), a national body responsible for developing the UK as a leader in IDTs. (Maier, 2017) Key Enablers are also recommended, including Financial Incentives, such as R&D Tax credits; Standards to govern digital implementation; and Access to data – building networks to share data and information. (Maier, 2017)

Since the review there have been number of focussed developments in the UK. The main initiative, the Made Smarter Adoption Programme was piloted in Northwest England. Since its inception over 3100 manufacturing SMEs have registered and over 500 IDT projects have been funded. (Gov.UK, 2023) The High Value Manufacturing Catapult Network, which helps bridge the gap between research and industry, has grown to over 50 locations to support innovations across the UK, working with nearly 22000 companies in the last decade. (Gov.UK, 2023) There have been a number of Policy papers published by the UK Government, including a *UK Digital Strategy* in October 2022, a *Roadmap for digital and data, 2022 to 2025*, The *UK's International Technology Strategy* in March 2023 and an *Advanced Manufacturing Plan* in December 2023. All reference the development and commitment to Industrial Digital Technologies to enhance UK manufacturing growth.

In the recent UK Government Autumn Statement, it was announced that the Made Smarter Adoption Programme which focussed on Northwest England is to be rolled out to all of England with the government allocating £16 million in 2025-2026, before working with the devolved nations of Scotland, Wales and Northern Ireland from 2026/2027. There will be an additional £50million in funding for apprenticeships, and Capital allowances on qualifying plant and machinery investments will be made permanent. (MakeUK, 2023)

Spotlight – Smaller demographic area - Wales

The Welsh Government released a report “*A manufacturing future for Wales: our journey to Wales 4.0*” in April 2023 discussing the manufacturing future for Wales. The manufacturing sector provided 150,000 jobs and contributed 16% of the national output of Wales at the time of the report highlighting that manufacturing is significant in terms of employment and Gross Value Added (GVA). (Welsh Government, 2023)

The report discusses the manufacturing sector can be a catalyst to economic prosperity in Wales and navigating the fourth industrial revolution is a key are to enable this. Strategic objectives are proposed, one of which is to “Strengthen collaboration between stakeholders to embrace technological change and deliver more commercial innovations at pace”. (Welsh Government, 2023)

Much of this objective is underpinned by new technologies and processes, but many of the Industry 4.0 technologies that have transformational potential for the manufacturing sector are under adopted.

	Fully adopted	Pilot project running	Thinking about its use/ plant to start a pilot project	Not currently used
Computer Aided Design (CAD)	65%	4%	13%	19%
Process Monitoring	36%	8%	16%	40%
Digital Models	30%	11%	13%	47%
Sensor Technologies	28%	2%	12%	58%
Robotics and Automation	25%	15%	17%	44%
Data Analytics Tools	20%	5%	15%	60%
Additive Manufacturing / 3D Printing	18%	14%	8%	59%
Connectivity (IOT)	11%	0%	22%	68%
Machine Learning / AI	9%	2%	11%	77%
Augmented Reality	0%	5%	9%	86%
Virtual Reality	0%	5%	5%	91%
Blockchains	2%	2%	95%	0%

Figure 9. Industrial Digital Technology Adoption (Welsh Government, 2023)

Investing in Research and Development and attracting more private and public investment to Wales is an important action for this objective. The Advanced Manufacturing Centre (AMRC) Cymru, created by the University of Sheffield has been successful in fostering collaborative research and embedding Industry 4.0 technologies in manufacturing companies such as Airbus, Hensol Distillery and The Pudding Company. *(Welsh Government, 2023)*

AMRC Cymru is a member of the High Value Manufacturing Catapult network of research centres and recently featured in an article posted in The Manufacturer discussing AMRC Cymru and its partnership with the University of Wales Trinity Saint David (UWTSD) to help lead Welsh businesses towards a smart, sustainable, and resilient future. *(The Manufacturer, 2024)*

2.3. Industry 4.0 Summary

Industry 4.0 offers numerous advantages to manufacturing companies. Examples include: Enhancing productivity, with technologies such as automation, data analytics and artificial intelligence to optimise production processes; Mass customisation using additive manufacturing and robotics to tailor products to customer requirements; Improved quality control, utilising IoT sensors and real-time data analytics to immediately and correct defects in the process; and Predictive Maintenance, by continuously monitoring equipment conditions with IoT sensors and Artificial Intelligence to analyse and anticipate when maintenance is needed before failure occurs. (*IoT.Business.News, 2024*)

With these benefits it would be assumed that the UK would be keen to adopt Industry 4.0, or Industrial Digital Technology to enhance the manufacturing sector.

Industry 4.0 is like previous Industrial Revolutions and does have factors that may limit its progression. Klaus Schwab published a book called 'The Fourth industrial Revolution' which discusses the impacts of Industry 4.0. A key topic is the potential risk to the progress of Industry 4.0. Schwab said:

“Still valid today is the lesson from the first industrial revolution – that the extent to which society embraces technological innovation is a major determinant of progress. The government and public institutions, as well as the private sector, need to do their part, but it is also essential that citizens see the long-term benefits”. (*Schwab, 2017a*)

Since the UK government initiated the Made Smarter Review 2017 progress has been made. The UK Government engaged industry experts to review the UK adoption of Industrial Digital technology, and has responded with new policies, investment and initiatives such the Made Smarter adoption programme and the High Value Manufacturing Catapult, both being expanded to be accessible to all areas of the UK.

Industry 4.0 has a wide scope of technologies, so to investigate the variety and adoption further the technology Low Power Wide Area Networks (LPWAN) is chosen. This study will evaluate the technology and its application in the UK.

3. Chapter 3 - Low Power Wide Area Networks (LPWAN)

3.1. LPWAN Technology Overview

A Low Power Wide Area Network (LPWAN) is a type of telecommunication network. It is a wireless communication network designed to connect devices that require long-range communication and has low power consumption. LPWANs are designed to have long battery life and able to transmit over long distances by reducing the frequency of communications and transmit at lower data rates. These attributes suit IoT devices, where an expandable, cost-effective network is required. (Exactitude Consultancy, 2023)

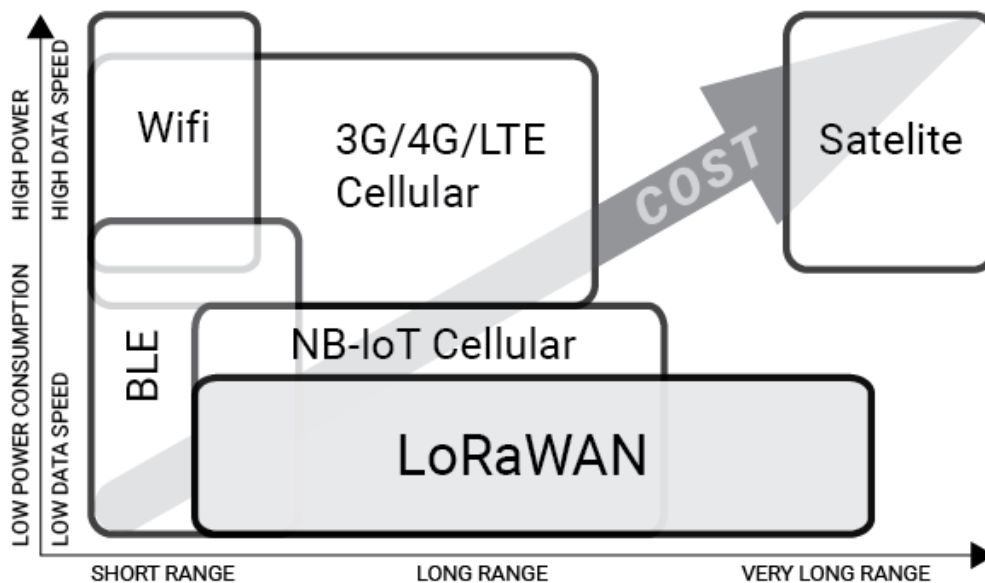


Figure 10. Communication Protocol chart – Data speed vs range, power consumption and cost. (BARANI, 2021)

Figure 10 shows LPWAN protocols such as LoRaWAN and NB-IoT classified with low data speeds, enabling low power consumption, resulting in a longer-range communication capability than Wi-fi and 3G/4G/LTE Cellular.

IoT end devices that are outdoors and require internet access could be limited by cellular connectivity. LPWAN technology can be the solution, especially if a remote application requires lesser amounts of data less frequently. For example, GPS tracking applications may only send data once every hour and the GPS device may move in and out of GSM network coverage. Connecting the GPS application to an LPWAN network can ensure connectivity to the internet via an LPWAN Gateway. It suits applications which require limited throughput, using small message sizes and short transmission intervals, as this reduces battery use, extending the life. (Gilchrist, 2016)

Comparisons of LPWAN and other communications protocols in Figure 11 focus on power consumption, latency, communication distance and data rates with LPWAN having a lower power consumption than GPRS and having a better communication distance than Zigbee and Wi-fi.

Table 1
Comparisons between GPRS and LPWAN technologies.

Technology	Power consumption	Latency	Coverage	Data rate
GPRS	High	Low	MCL 130 dB	Maximum 171.2 kbps
LPWAN	Low	Not guaranteed	MCL 150 dB	Adaptive from 0.1 kbps to 250 kbps

Table 2
Comparison of ZigBee, WiFi, and LPWAN technologies.

Technology	Communication distance	Maximum connection	Data rate
ZigBee	10–75 m	≤ 255	Maximum 171.2 kbps
WiFi	100 m	≤ 255	> 10 Mbps
LPWAN	3 km to city scale	≤ 50 000 (NB-IoT), ≤ 200 000 (LoRa)	Adaptive from 0.1 kbps to 250 kbps

Figure 11. Communication Protocol comparisons (Song, 2017)

There are a variety of LPWAN technologies, with different specifications. Market analysis by Exactitude Consultancy shows the top 3 LPWAN Technologies used globally in 2022:

LPWAN Market, by Technology, 2022

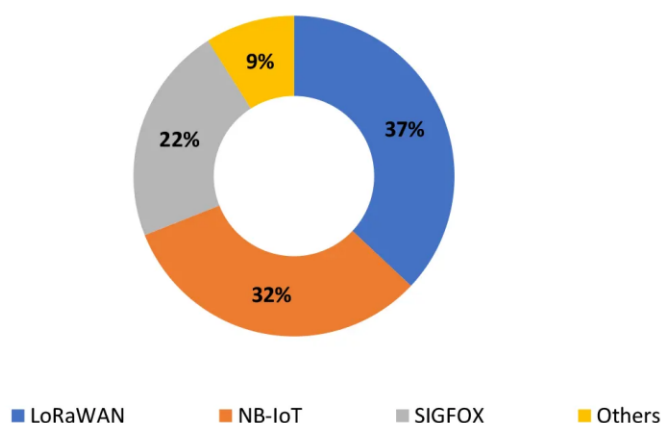


Figure 12. LPWAN Market share, by technology, 2022 (Exactitude Consultancy, 2023)

Figure 12 shows LoRaWAN technology was the most dominant in the LPWAN market in 2022. There has been an increasing demand for low-cost, low powered connectivity solutions, which LoRaWAN technology provides. NB-IoT however, is anticipated to experience large growth due to cellular network operators using NB-IoT to grow entirely new markets. (Exactitude Consultancy, 2023) Sigfox was developed in France, and was operating a network comprising 2600 base stations nationally when it filed for insolvency in 2022, slowing its impact on the LPWAN market. (Morris, 2023)

LoRaWAN

LoRaWAN was created by the start-up company Cycleo, later bought by Semtech. It is supported and standardized by the LoRa-Alliance which is a non-profit global alliance. LoRaWAN transmits data spread across bandwidths using chirp spread spectrums (CSS), the high spread factors enable higher transmission ranges with low data rates. LoRaWAN

communicates bi-directionally and uses different Classes to address the different latency required for IoT applications. It operates on un-licensed bands, so can be operated without a network Operator. (Mekki, 2018) LoRa operates in bandwidths from 433MHz to 868 MHz and has a transmission range of up to twenty kilometres in line of sight, and five kilometres in urban areas. (Amazon Web Services, 2021) The telecom operator KPN is referenced for deploying a LoRa network that covers the whole of the Netherlands. (Song, 2017)

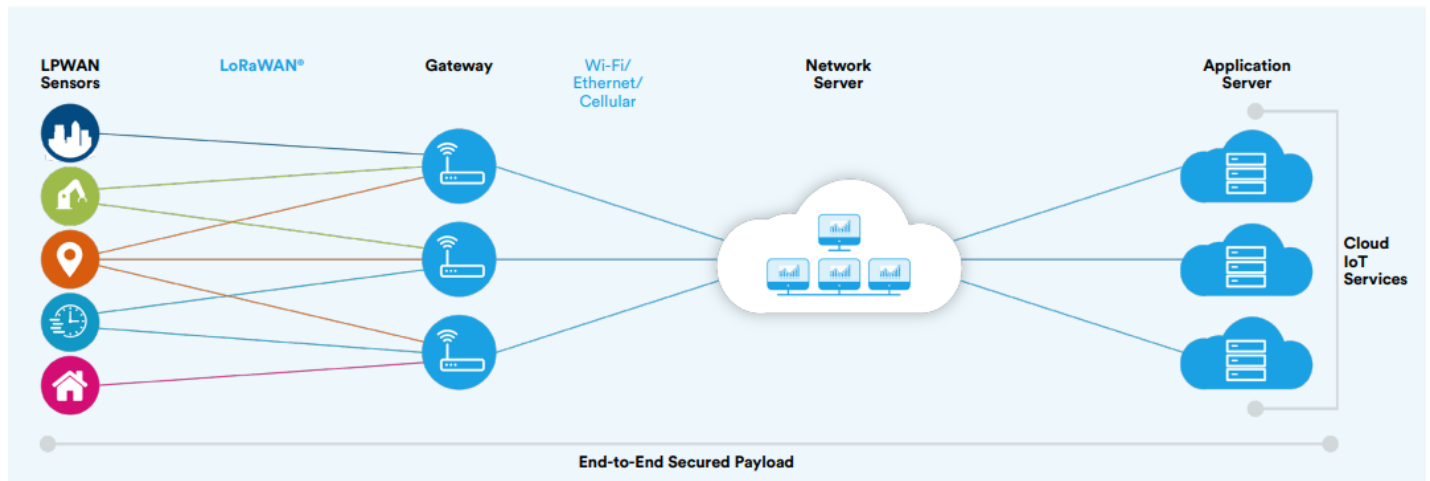


Figure 13. LoRaWAN Architecture (Beecham Research & LoRa Alliance, 2023)

Figure 13 is typical for most LPWAN protocols, connecting the LPWAN Sensors to a Gateway.

NB-IoT

Developed by the 3rd Generation Partnership Project (3GPP) the Narrowband Internet of Thing (NB-IoT) is a narrow band radio technology operating over licensed frequency bands. Evolving from LTE (Long Term Evolution) NB-IoT communicates at lower data rates and with less frequency, which requires less power. (Mekki, 2018)

NB-IoT is a wireless cellular network technology operating on a licensed spectrum defined by 3GPP. A cell is a geographical area in which radio frequencies can communicate with a transceiver station, such as a cell tower or a base station. Approximate transmission range for NB-IoT between IoT device and base station is one kilometre in urban areas and ten kilometres in rural areas. (Amazon Web Services, 2021)

NB-IoT operates on licensed frequency bands such as GSM (Global System for Mobile communications) - 700MHz, 800MHz and 900mHz, and is supported by telecom manufacturers such as Nokia. (Song, 2017) (Ogbodo et al., 2022)

Sigfox

Sigfox was developed in France in 2010 and transmits at an ultra-narrow band of 100Hz between 862MHz and 928MHz, with a maximum data rate of 100bps. This technical specification enables a low-cost design and low power consumption. Sigfox devices can transmit data as far as forty kilometres outdoors and ten kilometres indoors. (Mekki, 2018) (Amazon Web Services, 2021) Sigfox is now operating as Sigfox oG, owned by UnaBiz, who bought the company in 2022 after Sigfox had gone into receivership. (Burkitt-Gray, 2022)

Comparisons of LoRaWAN, NB-IoT and Sigfox

The 3 protocols can be compared using factors such as Quality of Service, battery life, range, costs, scalability and latency.



Figure 14. LPWAN Comparison by factor (Mekki, 2018)

Different Technologies suit different factors, for example.

- Costs – LoRaWAN devices can cost 3-5Euro whilst NB-IoT devices can cost >20Euros.
 - Payload – Sigfox is limited transmitting data at 12 bytes. NB-IoT can transmit up to 1600 bytes.
 - Latency – NB-IoT has lower latency than LoRaWAN (latency is the measure of time to transmit from one point to another)
 - Battery Life – LoRaWAN has a better battery life than NB-IoT, due to less frequent data transmissions.
 - QoS (Quality of Service) - NB-IoT has the better QoS, with frequent communications and faster transmission of data.
- (Mekki, 2018)

Case Studies

A report by Yonghua Song et Al compares LPWAN technologies for energy monitoring resulting in the recommendation of two LPWAN technologies, depending on the application. As part of China's Energy Roadmap set in 2016 China promoted the use of Smart Grids to monitor distribution networks in Rural areas without having licensed cellular coverage. LoRaWAN was proposed to connect end devices to a single base station (BS)

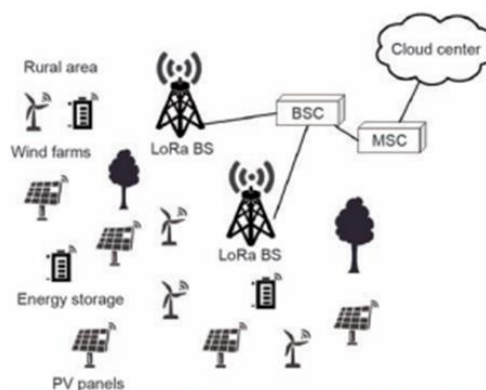


Fig. 2. Application scenarios of LoRa network in rural areas. BSC: base station control; MSC: multi-service control.

Figure 15. LoRaWAN network in rural area (Song, 2017)

Figure 15 shows Base Stations installed to communicate with renewable energy sources, such as Photo Voltaic (PV) panels and wind farms.

NB-IoT would be more suitable for urban areas, where licensed cellular networks are available. End devices would use the NB-IoT network to communicate with the cloud centre.

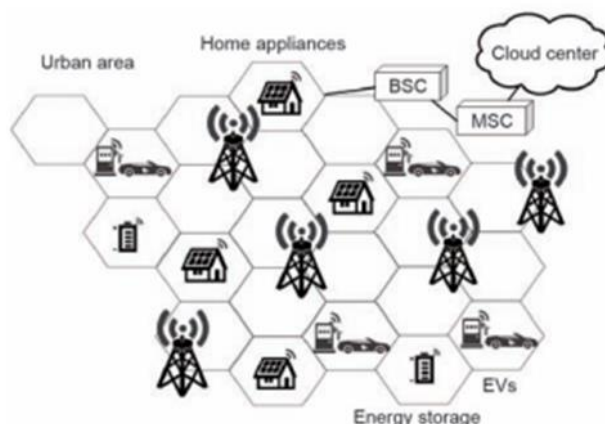


Fig. 3. Application scenarios of NB-IoT cellular network in a city.

Figure 16. NB-IoT network in urban area (Song, 2017)

In Figure 16 the cloud centre uses the NB-IoT network to communicate with Electric Vehicles (EVs) and home appliances throughout the city.

This article supports LPWAN as a solution for energy system networks, suggesting both LoRaWAN and NB-IoT are recommended, but in different applications. These interconnected Smart grids can be controlled more efficiently using these solutions, and support China's policy of using the internet to support smart energy grids. (Song, 2017)

Another Case study by Shobhit Jain et Al investigated the use of Smart meters to deliver Automated Meter Readings over vast areas of India with the use of LPWAN technology, with various pilots implemented in 2018. (Jain, 2018) Airtel Business partnered with Adani Energy Solutions to develop over 20 million smart meters which will be deployed in India. A government policy, India's smart meter programme is critical to digitalising a smart grid using NB-IoT and 4G technology to enhance coverage and security of data collecting and control. (TIMESOFINDIA.COM, 2024)

Kais Mekki's Article "Overview of Cellular LPWAN Technologies for IoT Deployment: Sigfox, LoRaWAN, and NB-IoT" discusses the factors of each technology, with recommendations for all three protocols, for different applications. Electric metering – NB-IoT preferred because of higher data rates and frequent transmission. Smart Building – Sigfox or LoRaWAN – temperature and humidity sensors not requiring continuous communication. LoRaWAN recommended for pallet tracking due to low cost, long battery life and reliable communication. The report discusses adoption giving examples of the Vodafone network piloting NB-IoT in Spain, and the Ministry of Industry and Information Technology in China announcing its decision to accelerate the commercial use of NB-IoT for utilities and smart city applications in May 2017. (Mekki, 2018)

A Synergy of 5G and LPWAN technology is addressed in Ogbodo's article " A Survey on 5G and LPWAN-IoT for

Improved Smart Cities and Remote Area Applications: From the Aspect of Architecture and Security", reviewing IoT device networks in Smart city and rural applications. It discusses the expansion of IoT device use which would require a unified 5G and LPWAN-IoT network to support integrations with emerging technologies over wide areas and improve smart cities and remote IoT applications. (Ogbodo et al., 2022)

These example case studies indicate that LPWAN technology is used in a variety of global locations for a variety of applications, sometimes linked with other technologies to create synergised opportunities for communication networks. Global networks are available to support LPWAN protocols. For example, The Things Network is a global Internet of Things ecosystem that creates networks, devices and solutions using LoRaWAN, operating over 153 countries, and 21.2k members. The Things Stack is a global network server, which supports services and tools to manage millions of LoRaWAN devices. (The Things Industries, 2024) Sigfox oG Technology operates the oG Network that is available in over 70 countries and connects over 11 million devices. (Sigfox, 2024) NB-IoT also has coverage globally, operating in over 60 countries using over 100 providers or network operators to enable NB-IoT. (Deutsche Telekom IoT GmbH, 2024)

3.2. LPWAN Technology in the UK

LPWAN Technology is being used globally, LoRaWAN and Sigfox via global unlicensed networks, and NB-IoT globally by licensed network operators.

LoRaWAN has grown in the UK, with over 1500 LoRaWAN gateways in operation to provide network access to over 100 The Things Network communities and used in numerous applications across the country. (The Things Industries, 2024) Connectivity providers such as Connexion, are also operating LoRaWAN networks across the UK, providing a technology partner service for users to implement LoRaWAN solutions. This network solution has been used by Hull City Council and Icosa water for Smart buildings and Smart water monitoring. (LoRa Alliance, 2021) In 2023 Connexin announced it is set to expand the network with plans to connect an additional 400,000 IoT smart water meters in partnership with utilities Severn Trent Water and Yorkshire Water. The real-time insights on water usage can swiftly detect leaks and reduce water loss. (Rogerson, 2023) Anglian Water, a large water utility provider in the UK, engaged Flowserve to implement a Predictive Maintenance system (Pd.M.). Condition Based Monitoring (CBM) sensors operating with LoRaWAN wireless technology were fitted on a range of equipment to collect vibration, temperature and pressure data. The data is transferred securely via LoRaWAN to the Insight Portal which is monitored by technicians. After successful pilot projects Anglian Water implemented a full CBM framework to cover up to 900 assets. The system provided technical insights and recommendations to plan maintenance better and improve efficiency, productivity and reliability of the equipment. (Beecham Research & LoRa Alliance, 2023)

NB-IoT networks are provided by several operators in the UK. Vodafone's NB-IoT network covered 98% of the UK in 2021, using it to complement its other connectivity services, such as 4G and 5G. The NB-IoT network is designed for low-bandwidth devices for non-time sensitive use cases, such as environmental monitoring, supporting a 5G network which provides real-time, data sensitive analytics. (Vodafone Limited, 2021) Vodafone has used NB-IoT to help the Department for Environment Food and Rural Affairs (DEFRA) to monitor tree growth. In areas that mobile connectivity

could not reach Vodafone's IoT sensors have been attached to nine oak trees in Forestry England to measure tree growth, air and soil temperature. Data from these sensors is sent over Vodafone's NB-IoT network to a dashboard for analysis. *(Vodafone Limited, 2024)* BT launched its NB-IoT network in 2024, covering 97% of the UK, supported by the EE mobile network. BT's new network will enable low-data-demand applications, such as underground water or street lighting sensors to be connected over a smart network. The rollout will help fast-track smart cities using NB-IoT for energy monitoring, storage and distribution. *(BT, 2024)* O2 is another network provider who is launching NB-IoT in 2024, to enable businesses to support millions of connected devices for applications such as Smart Grid, Smart buildings and Asset. *(Telefonica UK Limited, 2024)*

Sigfox coverage is operational in England and Ireland, with rollouts in progress for Scotland and Wales. It is operated by Heliot Europe, a provider of IoT connectivity solutions specialising in deployment of Sigfox oG. *(Heliot Europe GmbH, 2024)* An example case study - Heliot are working with Cisterniser to improve legionella detection in offices and hospitals, fitting Cisterniser's Linkthru temperature monitoring units (TMUs) in sometimes remote locations. SIM cards and cellular solutions were considered too costly, so Heliot's Sigfox oG network was selected. Heliot and Spica technologies designed new TMU sensors, and the network was managed by Heliot. *(Rogerson Steve, 2023)*

3.3. LPWAN Summary

There is a variety of Low Power Wide Area Network protocols, with LoRaWAN, NB-IoT and Sigfox the most dominant. The technology is used in a variety of applications, categorised below:

LPWAN Market, by Application 2022

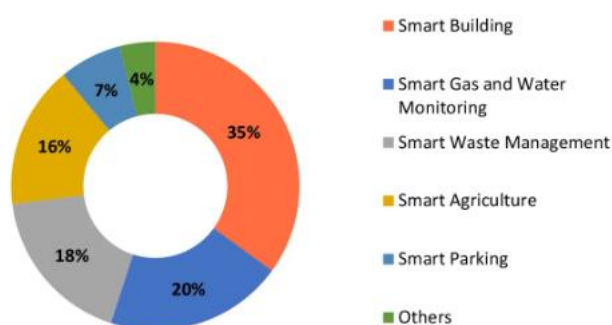


Figure 17. LPWAN Market share, by Application 2022 *(Exactitude Consultancy, 2023)*

Figure 17 shows the most popular applications are Smart Buildings and Smart Energy Monitoring. Both applications require low powered devices, in situations like temperature monitoring, energy usage and smart lighting which do not require high data rates to be transmitted. The spread of devices in these settings, such as Connexion's water meters prioritises long range networks to enable many devices in a wide area to communicate reliably with limited Gateways.

Globally the focus on Smart grids, and Smart cities have encouraged governments such as India and China to set standards and policies for energy efficiency projects that utilise LPWAN technology. In 2022, NB-IoT was a government

standard in China, resulting in all mobile networks in China offering it for IoT applications. *(Beecham Research & LoRa Alliance, 2023)* India's government launched India's Smart Meter National Programme (SMNP) aiming to replace 250 million conventional energy meters with smart meters by 2025. Airtel Business partnered with Adani Energy Solutions to develop over 20 million smart meters using its IoT platform based on NB-IoT and 4G. *(Jones, 2024)*

The UK has seen wide adoption in large businesses and institutions such as Anglian Water and Hull city council and Cistermiser, all using technology partners to implement LPWAN solutions. The UK has an Energy Digitalisation taskforce led by Business, Energy & Industry Strategy (BEIS), Ofgem and Innovate UK, following the Energy Digitalisation Strategy, to focus on modernising the energy system and drive clean growth towards net zero emissions by 2050. The future net zero energy system will comprise millions of assets which need to be integrated efficiently and securely. *(Gov.UK, 2022a)* Funding provided by Made Smarter, Innovate and the Digital Catapult could incorporate projects that utilise LPWAN technologies to deliver the smart cities and networks required in the UK.

LPWAN is being encouraged by technology providers and network operators. NB-IoT is being adopted and implemented by O2, Vodafone and BT globally and in the UK, using it as a solution to the remote or inaccessible areas where 5G may be unreliable. NB-IoT is a protocol that operates in the licensed bands enabling these network operators to control and develop it. Alternatively, LoRaWAN is driven by global networks creators such as Connexion, and community champions, with the Things Network providing resources to connect and operate a global LoRaWAN network. Both protocols are often in conjunction 4G/5G to deliver reliable communications from gateway to cloud.

However the variation can cause confusion for users, who may not understand which protocol to use, relying on technology partners, such as Heliot, Vodafone and Connexion to help design and implement the LPWAN solution. Another risk is 5G sensors. Sensor-works are working with CENSIS to develop a 5G sensor that monitors the condition of equipment, using vibration and temperature feedback to determine Predictive Maintenance. 5G can transmit more data, faster than LPWAN, and can communicate straight to the cloud, bypassing the requirement for a gateway. *(O'Sullivan, 2023)*

For UK Manufacturing there are numerous opportunities LPWAN implementation to deliver benefits. The adoption may depend on knowledge, access to funding, access to technology partners and access to the devices and systems required.

4. Chapter 4 - Industry 4.0 and LPWAN – Industrial Professionals

4.1. Research Interviews - Industrial Service Providers

A selection of industrial service providers has been interviewed to research the awareness and use of Industry 4.0 and LPWAN technologies. The participants include local service providers, and some who service the whole of the UK and multinational companies.

Basic Interview Questions

1. Are you aware of Industry 4.0 technology?
2. In your opinion, has Industry 4.0 been adopted amongst your customers.
3. Are you aware of Low Power Wide Area Networks (LPWAN)?
4. In your opinion, has LPWAN been adopted amongst your customers.

Refer to [Appendix A for Research Interviews](#) (CTRL+click)

4.2. Interview - Industrial Service Providers Discussion

Mark Clifton – Castle Controls Solutions Ltd

Mark has been in the industry for over 30 years. Automation and electrical control systems are the main core of his business. Based in Nottingham, England he has six engineers who design and implement projects from production line electrical control upgrades to complete new system design and manufacture. *(Castle Control Solutions Ltd, 2024)*
(Clifton, 2024)

Mark's responses were unexpected. Considering his business involves upgrading technology, Industry 4.0 awareness was low, and demand limited. Customers were requesting SCADA systems and wireless communications, but mainly using cellular communications. This indicates that his customers are either not aware of Industry 4.0, or wireless solutions such as LPWAN, or they do not consider it a benefit. Evaluating the supplier/customer relationship, Castle Controls would be considered as the technology partner, so if the technology partner has low awareness, then the Industry 4.0 solutions may not be available to the customer. The wireless offering may only be of a cellular nature such as 4G/5G, as Mark is unaware of alternative wireless solutions such as LPWAN. *(Castle Control Solutions Ltd, 2024)*
(Clifton, 2024)

David McCallum - Templegate

David is based in the South Wales area, having worked for Electrical Industrial suppliers for 20 years. Templegate is an

Electrical wholesaler for all types of businesses across the UK. David is fully aware of Industry 4.0 from a personal curiosity of the topic, having completed a master's degree in Renewable Energy. (McCallum, D., 2024)

Being a wholesaler Templegate have access to various suppliers, to provide products for numerous customers. Both suppliers and customers are not discussing Industry 4.0 with David. He gives his opinion to why - *“cost, lack of skills and experience within the industry 4.0 sector, including the social and economic effects are affecting the progression.”* (McCallum, D., 2024)

Tony Dobbs – Industrial Automation and Control (IAC)

Tony is based in Newport, South Wales and is the Service and Training Director. IAC provide electrical and automation support to manufacturing businesses, across the UK and has a division in South Africa. (IAC Ltd, 2024) (Dobbs, 2024)

Tony and IAC are aware of Industry 4.0, involved in network designs and integration of IoT. Recent customer requests include smart sensors and cloud computing. IAC are not a distributor, so are not involved with source and supply of IoT devices unless requested to do so. The IAC website does not include Industry 4.0 case studies but may be updated in 2024 to include such projects. This indicates that the customer requirement is the reason for the involvement in Industry 4.0, rather than a supplier led offering. (IAC Ltd, 2024) (Dobbs, 2024)

Mark Harrison – PCS UK Ltd

Mark is based in Buxton, Derbyshire, has had 30 years in electrical contracting and now manages business development across the UK. PCS are electrical contractors who provide electrical and controls installations, network installations, electrical maintenance, and provide spare parts across the UK. (PCS UK Ltd, 2023) (Harrison, 2024)

Mark is aware of Industry 4.0 and the business is getting more involved in Industry 4.0 with a customer, Nestle. Usual business would include Automation solutions but using hard wired network systems such as Modbus, Profibus, Ethernet and Fibre Optic. Remote VPN (Virtual Private Networks) are managed via Ewon gateways for remote access to site networks. Ewon gateways such as Ewon Cosy+, Ewon Flexy and Ewon Netbiter, connect to automation devices such as PLCs through Ethernet, serial or USB interfaces. They provide remote connections via an ethernet, wi-fi or cellular network (3G/4G) to establish a VPN connection Ewon's industrial cloud. (HMS Networks, 2022) (PCS UK Ltd, 2023) (Harrison, 2024)

PCS have used Industry 4.0 technology with the use of Ewon, and the industrial cloud network. However, they are not aware this is an Industry 4.0 technology. Ewon are not using LPWAN, but conventional wireless technologies to provide wireless network capabilities. Informed Industry 4.0 technology engagement has been started, but at the request of a customer which is a large multinational company, Nestle. (PCS UK Ltd, 2023) (Harrison, 2024)

Mike Faulkner – UK Windows and Doors Group Ltd (UKWDG)

Mike was the IT Manager of the network architecture for UK Windows and Doors Group Ltd, a uPVC windows and doors manufacturer operating from 6 sites across the UK. He was responsible for the IT infrastructure of the business. Mike

was interviewed to understand the IT exposure to Industry 4.0.

Mike is fully aware of Industry 4.0 technologies, although constrained to implement them at UKWDG due to obsolescence and data integrity risks. A technology upgrade was required for data network servers, but cloud opportunities were too costly, and internal resource was too limited to support the project. An upgrade from magnetic to solid state hard drives was implemented to mitigate immediate risks. With other risks and financial constraints, the minimum upgrade solution was chosen. *(Faulkner, 2023)*

Mike is fully aware of Low Power Wide Area Networks (LPWAN), using it in his personal life. A self-proclaimed hobbyist he has a keen interest in network technologies and has a LoRaWAN gateway providing a network for local businesses, which provides a financial gain. *(Faulkner, 2023)*

His perspective of LoRaWAN adoption is shared and provides an independent opinion of why LoRaWAN adoption has been slow.

- Limited Coverage – to support a network there must be sufficient gateways. Regionally there may be gaps in coverage, so may not be adopted due to inconsistency.
- Competing technologies – NB-IoT and LTE-M provide similar functionality as LoRaWAN, both being cellular options, which may be better promoted by cellular network providers.
- Market awareness and coverage – the awareness of these technologies in the UK may not be adequate to ensure adoption and must rely on cellular network providers and IoT manufacturers to promote them.
- Industry Focus – other wireless and IoT connectivity options may be chosen by industry and businesses, depending on specification and use.
- Regulatory factors – LoRaWAN among others are unregulated networks. Policies and regulatory change could impact these technologies. If unlicensed networks require regulating and licensing, then costs may be incurred which would reduce the benefit of using them. *(Faulkner, 2023)*

Matthew Wallace – Schneider Electric

Schneider Electric is a global company with various electrical solutions. Schneider UK is a division that provides the following solutions:

- Automation and control
- Electrical distribution
- Building management
- Critical Power and Cooling Solutions
- Electrical Distribution
- Installation Systems and Control
- Medium Voltage Distribution and Energy Automation
- Solar

(Schneider Electric, 2024)

Matthew is the Digital Buildings Sales Director for Digital Energy in the UK and Ireland for Schneider Electric UK, with over 14 years of building services experience.

Matthew is fully aware of Industry 4.0 technology with it being prevalent in current projects. He refers to it as marketing language, hinting that it is a term used to sell new ideas and products to the market. Schneider have been promoting it for over 10 years, with adoption only now occurring, due to the need for energy monitoring solutions to reduce energy and sustainability agendas. Schneider Electric sell IoT products that already utilise LPWAN protocols such as Zigbee, LoRaWAN and Ecocean, which Matthew is involved in. His opinion is that LPWAN technology may not be widespread adopted. 4G networks are a cheap solution to large networks. Energy data in highly regulated sectors require reliable data, so only localised wireless networks would be considered. Wide Area Networks have a risk of lost data, which would not be acceptable for auditable data. Another challenge is from more wireless technologies overlapping into other bandwidths, which could cause miscommunications. *(Wallace, 2024)*

Marc Lewis - Parmley Graham Ltd

Parmley Graham is an Automation and Control distributor. There are 11 branches throughout the UK providing products and services to all sectors of UK industry. Parmley Graham are a SIEMENS Approved partner, giving them access and support from SIEMENS directly. This has enabled Industry 4.0 access and support, due to SIEMENS operating as global providers of automation and control products and services. *(Parmley Graham Ltd, 2024) (Lewis, 2024)*

Marc references that this partnership has enabled Parmley Graham to be educated and supported in Industry 4.0 technologies and to deliver solutions to its customers. SIEMENS assisted Parmley Graham with an innovation centre in their headquarters in Gateshead to showcase the Industry 4.0 technologies available. *(Parmley Graham Ltd, 2024) (Lewis, 2024)*

Although Marc is not aware what LPWAN technologies are he also states that TATA steel has implemented a LoRaWAN network in its steelwork's facility in Port Talbot. TATA Steel is a global steel manufacturer, with a facility in Port Talbot. The site is over 3km long, so a Low Powered Wide Area network could be useful for collating data from the various production processes at the port Talbot site. Marc seems aware of the technology, but not as the term LPWAN. *(Lewis, 2024)*

4.3. Interview - Industrial Service Providers Conclusion

A varied base of candidates was used for service provider interviews, all bringing varied responses. Small businesses, large businesses and alternative sectors (IT) have been interrogated for their perspective on Industry 4.0 and LPWAN technologies.

All participants are aware of Industry 4.0. in varying levels. The electrical service providers - Castle Control, Templegate, and PCS having limited awareness of Industry 4.0, with limited customer requirement for such technology. These businesses have direct engagement with UK Manufacturers of all sizes and indicates that those businesses are not aware or require Industry 4.0 technology. PCS, IAC and Parmley Graham are all involved with Industry 4.0. - PCS via Nestle, a global multi-national company, IAC due to recent customer requirements and Parmley Graham influenced by

its Partnership with SIEMENS. This partnership with SIEMENS enables Parmley Graham to be a technology partner to larger companies, with an example of the global multi-national company Tata Steel recently being supported by Parmley Graham to implement a LoRaWAN solution.

With personal interest Mike Faulkner's is engaged with Industry 4.0 but his perspective deduces that costs, awareness are limited in the company he worked for and may also be a limiting factor for Industry 4.0 adoption in the UK. He also referenced the variety of competing LPWAN technologies and alternative options for wireless networks, which would make it confusing for Users to commit to a type.. *(Faulkner, 2023)*

Matthew Wallace works for a global company with expertise in the field of electrical technology. Schneider Electric, and Matthew are directly involved in Industry 4.0 technology. From Matthew's experience it has taken over 10 years to start seeing adoption, triggered by a requirement to provide a solution to a particular issue – energy usage and sustainability. *(Wallace, 2024)*

The conclusion from this area of research is that smaller, or businesses with lower disposable resources are not focussed on Industry 4.0 so smaller service providers are not actively selling it. Large companies such as Nestle and Tata Steel have more available resources, so can strive to adopt more innovative technology. Large providers of the technology, such as Schneider and SIEMENS have been actively marketing Industry 4.0 technology, but only recently seeing adoption; to provide solutions to particular problems.

With regards to LPWAN, four of the subject group were experienced in implementation. Tony Dobbs from IAC recently involved in IoT projects, Mike Faulkner for personal projects, Matthew Wallace seeing it used by Schneider for IoT applications and Marc Lewis implementing a network in Tata Steel with Parmley Graham. Both Mike Faulkner and Matthew Wallace have reservations with its adoption across the UK. Cellular solutions such as 4G/5G are easier, and more available, and there may be too many LPWAN solutions, with limited awareness in the UK or focus from technology providers. This is supported with Mark Harrison's remote access solution Ewon, only being available with Ethernet, Wi-fi and 3G/4G. This indicates that there are many options available, but larger companies such as Tata Steel are implementing technologies such as LoRaWAN, which may influence other companies to copy or adopt similar technology.

5. Chapter 5 - Industry 4.0 and LPWAN Adoption in UK Manufacturing

5.1. Research – End User Surveys

To research Industry 4.0 and LPWAN adoption in UK Manufacturing surveys were circulated to a range of End Users - engineering personnel. Participants are employed in the UK, and are engineering trained, involved in repairs, maintenance, projects and manufacturing operations. This has given a wide-ranging view of equipment, operational requirements and spare parts inventories of their businesses and what is available from parts and equipment suppliers.

Criteria for survey participants : 1.Varied industry 2.Varied location 3.Varied engineering level – engineer, supervisor, manager

Varied Industry

Different Industries will have different processes, therefore different equipment. The equipment may be of different technology and lifecycle.

Varied Location

The author is based in South Wales, so available contacts are based in the South Wales and Southwest England areas, with a small number of subjects from further afield.

Varied Engineering level

The position held by the participant may allow more insight into technologies. For example, managers, or project engineers may have a wider scope of technology and more inclined to research new technologies for projects, whereas engineers covering maintenance activities may not have the same exposure.

Survey Participants = 23

Company	Industry	Location	Number of participants
UK Window and Door Group Ltd	Fenestration	UK Wide	2
GC Windows	Fenestration	Pontypool, South Wales	1
Solar Windows	Fenestration	Bedwas, South Wales	1
Evolution Windows	Fenestration	Bedfordshire, England	1
Fillcare Ltd	Cosmetic Contract Manufacturing	Pontyclun, South Wales	2
Warburtons	Food Manufacturing	Bristol, England	2
Lucozade Ribena Suntory	Beverage Manufacturing	Coleford, England	1

Coppice Alupack	Food Packaging supplier	Bridgend, South Wales	1
Sofidel	Tissue Paper Manufacture	Baglan, South Wales	1
Etex BP	Building Materials	Avonmouth, England	2
Knauf	Building Materials	Pontypool, South Wales	1
Industore	Industrial storage	Cardiff, South Wales	1
Sony	Electronics Manufacture	Bridgend, South Wales	1
Bristol Waste Company	Recycling	Bristol, England	1
Roydon Bottle recycling	Recycling	Blackwood, South Wales	1
Envirowales	Recycling	Tredegar, South Wales	1
National Grid	Electricity Supply	UK Wide	1
Highadmit	Electrical Installation	Llantrisant, South Wales	1
JPS CBM	Reliability Services	UK Wide	1

End User Survey

Survey Monkey was used to create an online survey format, and the application created a link for the participants to receive and use to access and complete the survey. (SurveyMonkey, 2024)

Refer to Appendix B for Interview format. (CTRL+, click)



Survey Link - <https://www.surveymonkey.com/r/LMD9DFG> (SurveyMonkey, 2024)

Question 1

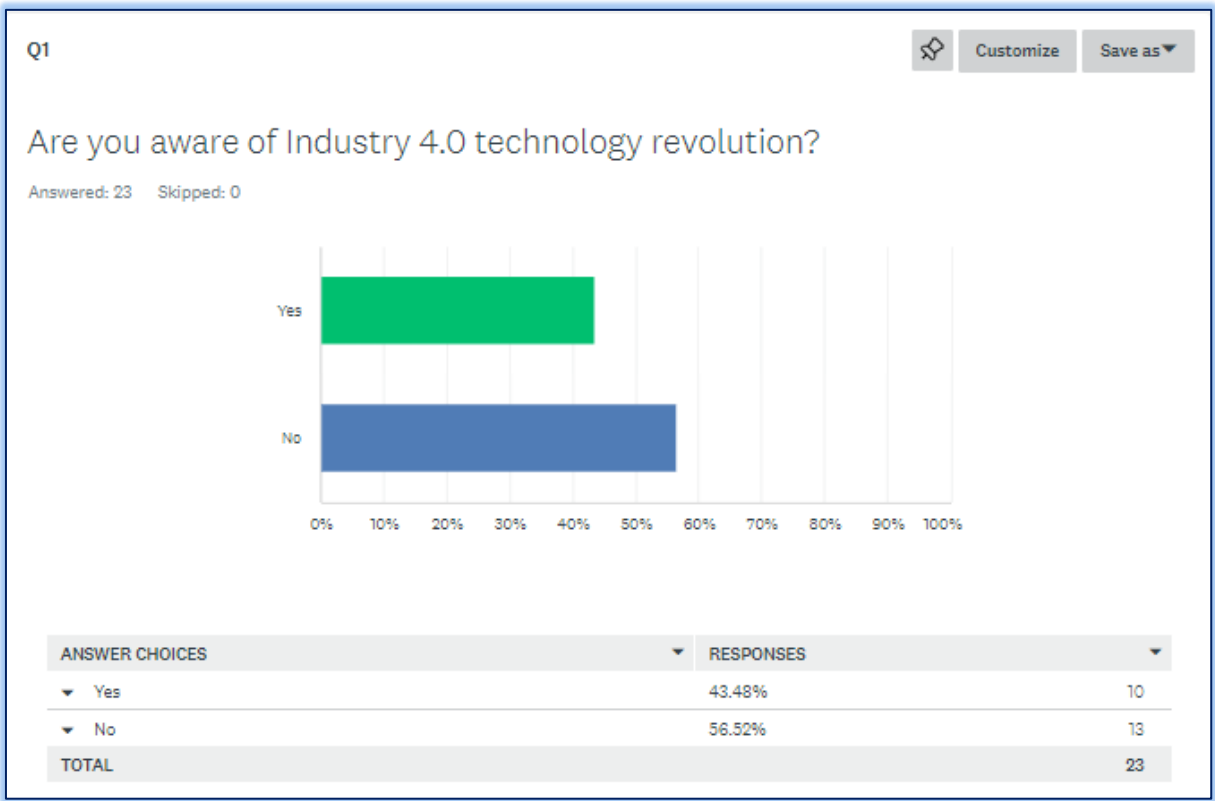


Figure 18. Awareness of Industry 4.0 technology revolution (SurveyMonkey. 2024)

- 43% (10) of participants were aware of Industry 4.0 technology.

Question 2

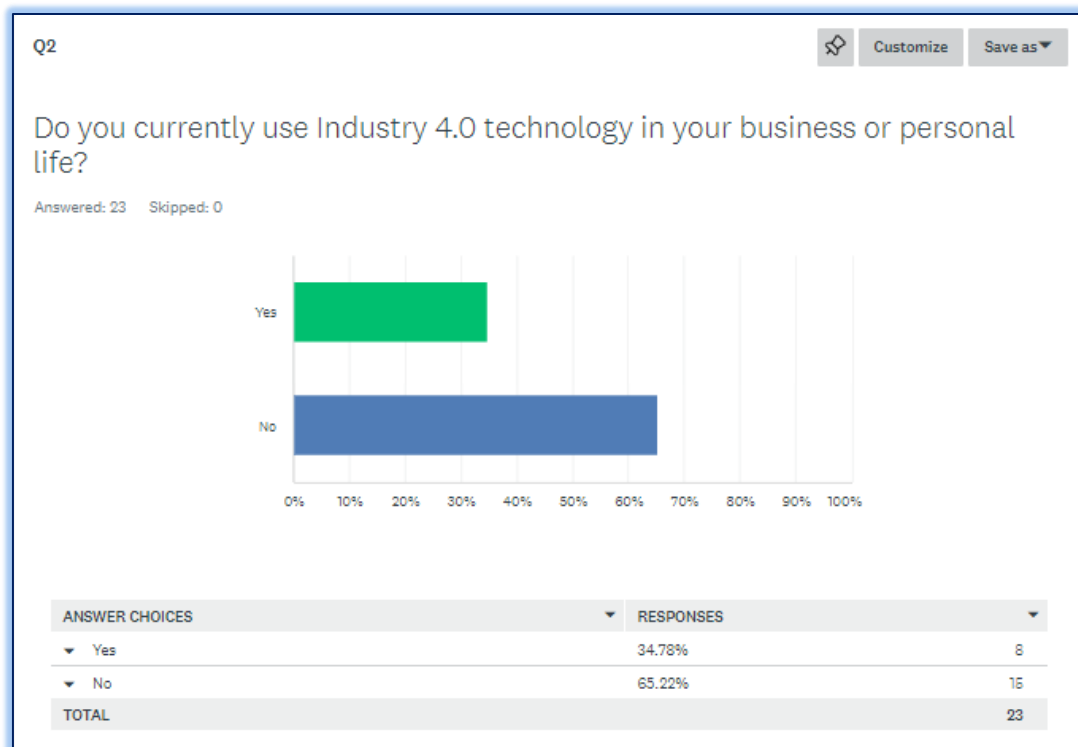


Figure 19. Industry 4.0 technology currently used in business or personal life. (SurveyMonkey. 2024)

- 35% (8) of participants use industry 4.0 technology.

Question 3

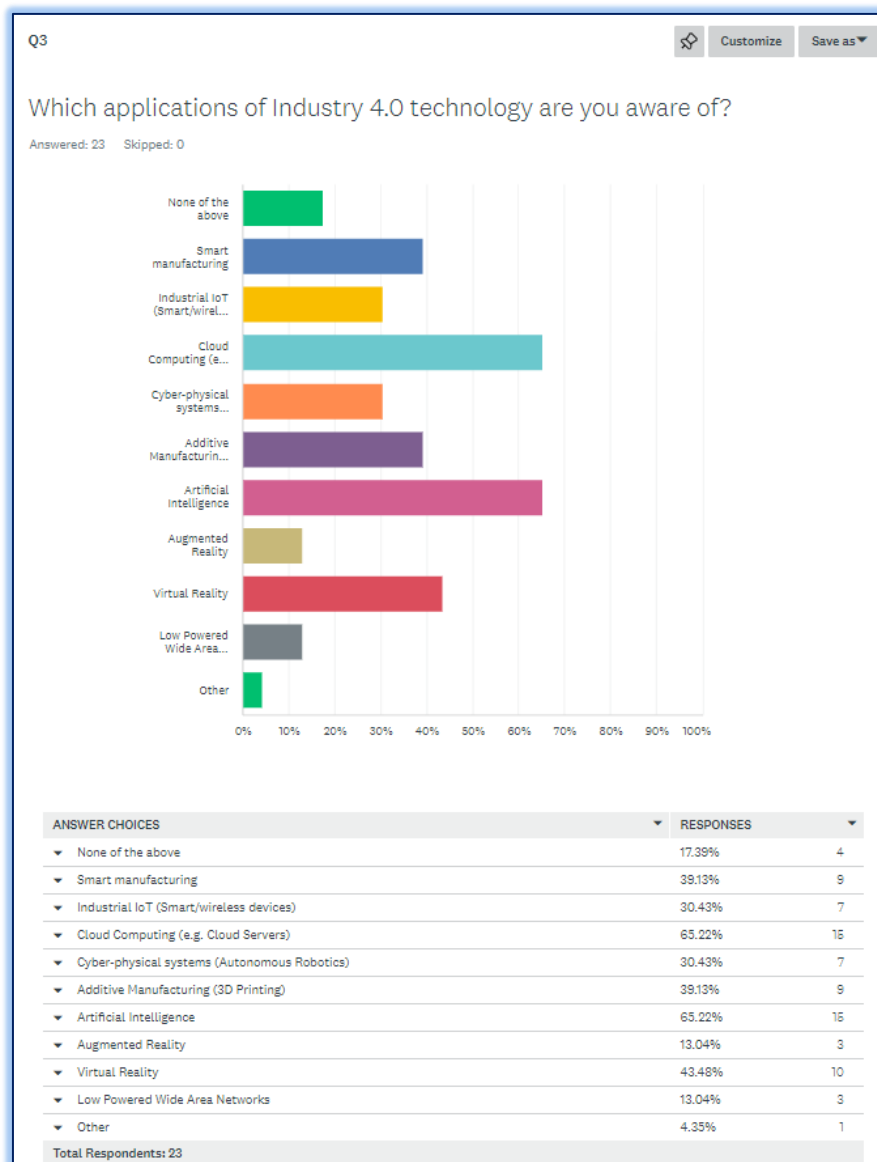


Figure 20. Awareness of the Applications of Industry 4.0 technology. (SurveyMonkey. 2024)

Rank	Percentage	Number of Participants	Technology
1	65%	15	Artificial Intelligence
2	65%	15	Cloud Computing
3	43%	10	Virtual Reality
4	39%	9	Additive Manufacturing (3D Printing)
5	39%	9	Smart Manufacturing
6	30%	7	Cyber Physical Systems (Autonomous Robotics)
7	30%	7	Industrial IoT (Smart/wireless devices)
8	17%	4	None of the above
9	13%	3	Low Power Wide Area Networks
10	13%	3	Augmented Reality
11	4%	1	Other

Table 1. Industry 4.0 technologies the participants are aware of.

Question 4

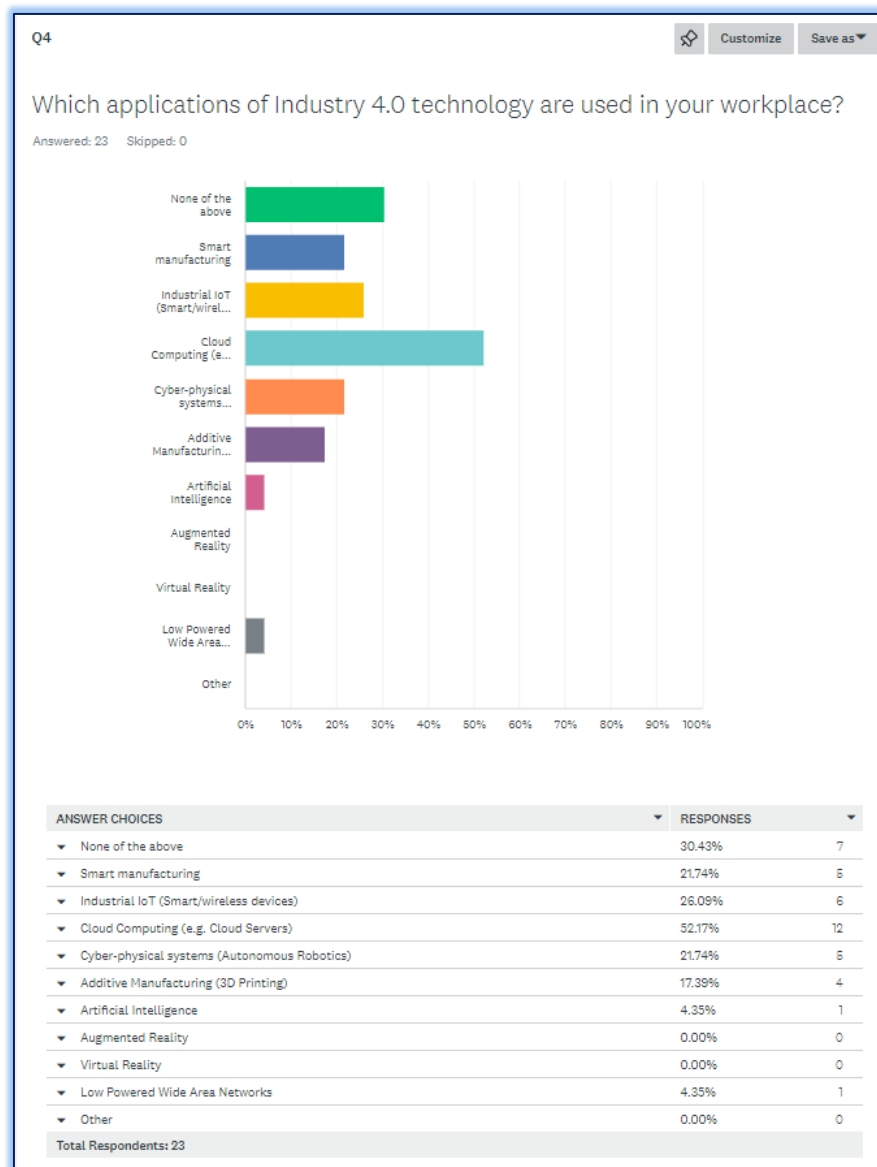


Figure 21. Applications of Industry 4.0 technology which are used in the workplace. (SurveyMonkey. 2024)

Rank	Percentage	Number of Participants	Technology
1	52%	12	Cloud Computing
2	30%	7	None of the above
3	26%	6	Industrial IoT (Smart/wireless devices)
4	22%	5	Cyber-physical systems (Autonomous robots)
5	22%	5	Smart Manufacturing
6	17%	4	Additive Manufacturing (3D Printing)
7	4%	1	Artificial Intelligence
8	4%	1	Low Power Wide Area Networks
9	0%	0	Augmented Reality
10	0%	0	Virtual Reality
11	0%	0	Other

Table 2. The technologies the participants used in the workplace.

Question 5

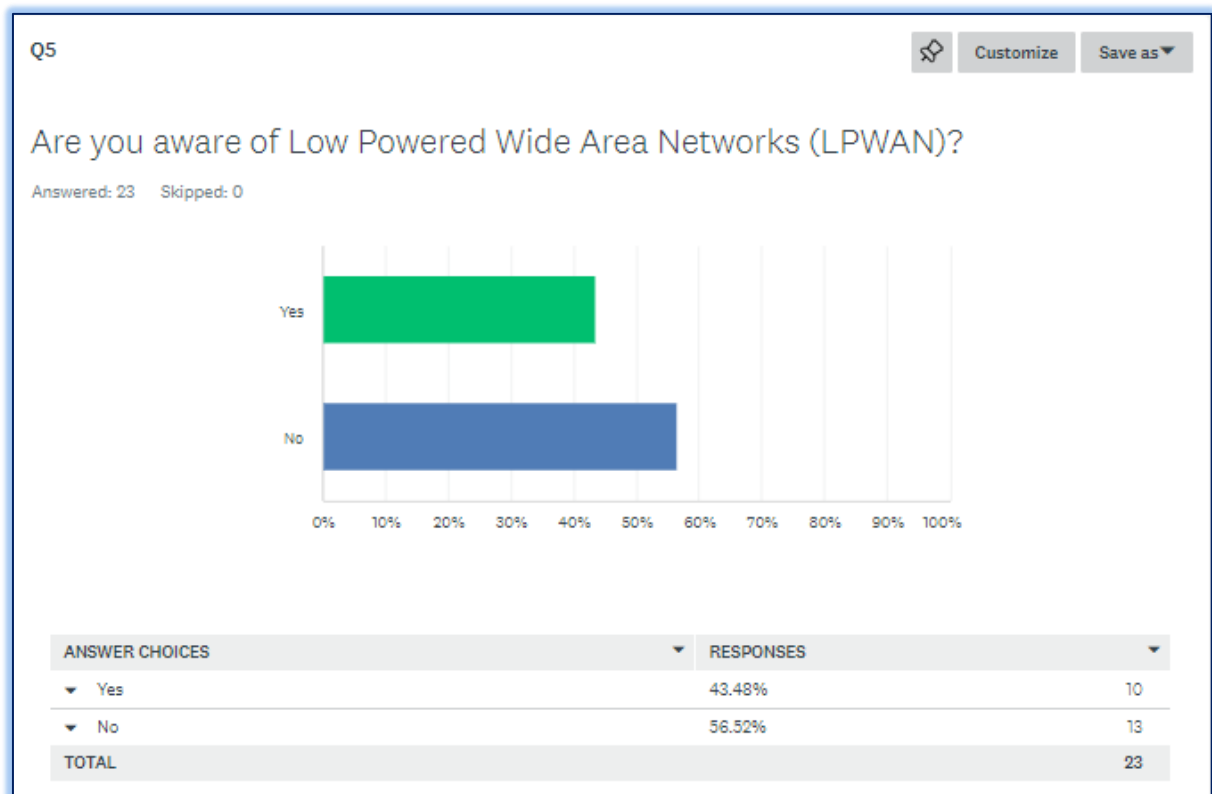


Figure 22. Awareness of Low Power Wide Area Networks. (SurveyMonkey. 2024)

- 43% (10) of the participants were aware of Low Power Wide Area Networks (LPWANs).

Question 6

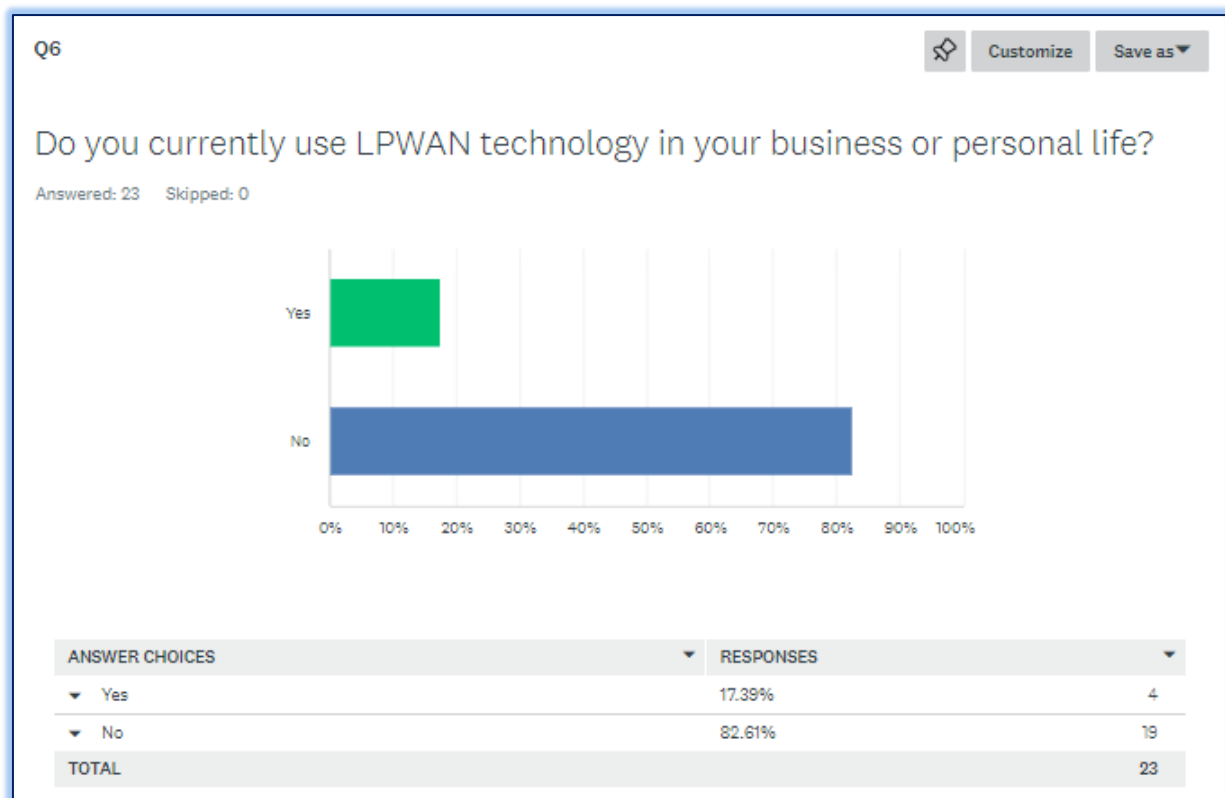


Figure 23. Current use of LPWAN technology in business or personal life. (SurveyMonkey. 2024)

- 17% (4) participants stated LPWAN are in use in the participants business or personal life.

Question 7

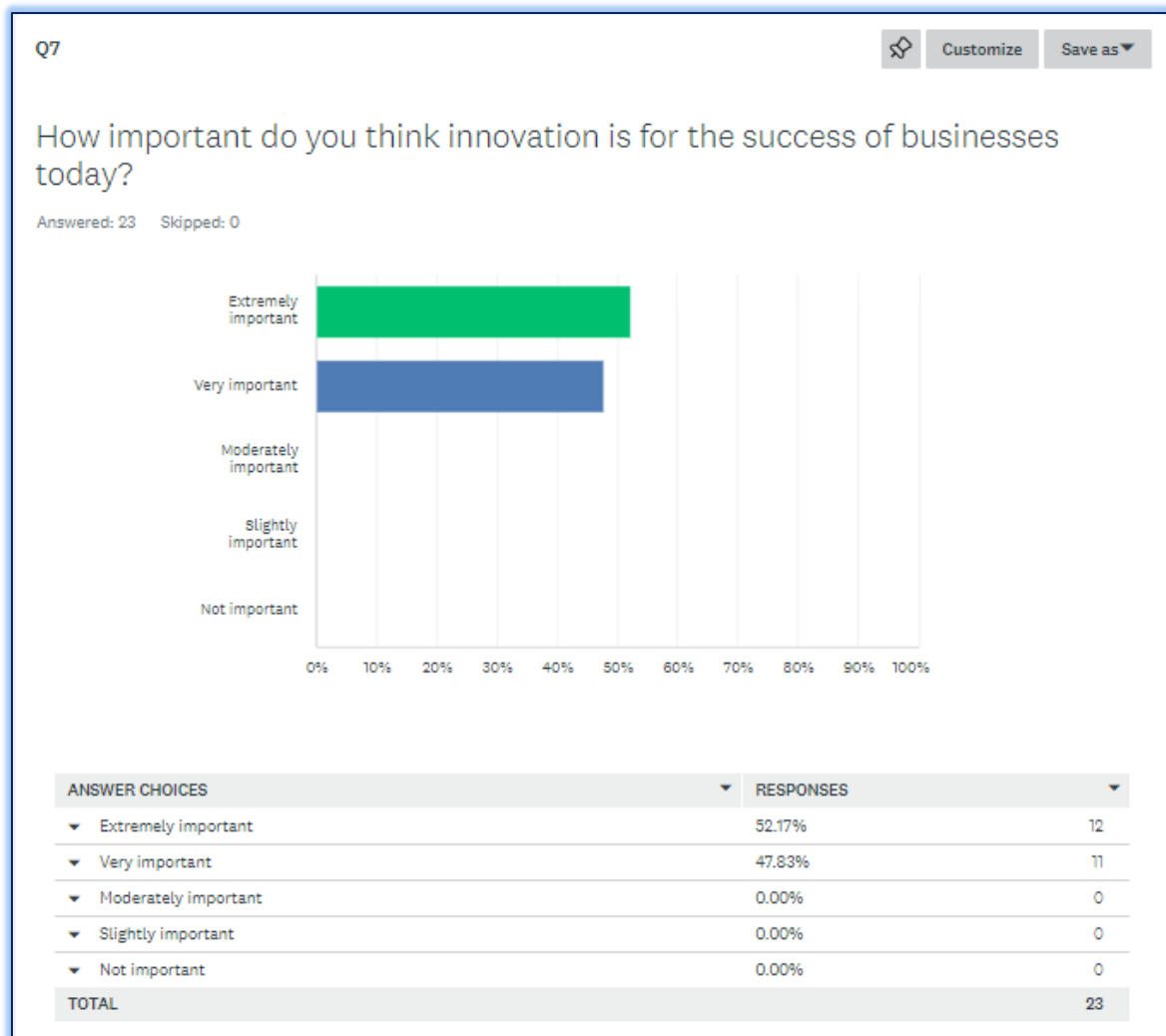


Figure 24. Importance of innovation for the success of business today (SurveyMonkey. 2024)

- 52% (12) of the participants consider innovation Extremely important.
- 48% (11) consider innovation Very important.

Question 8

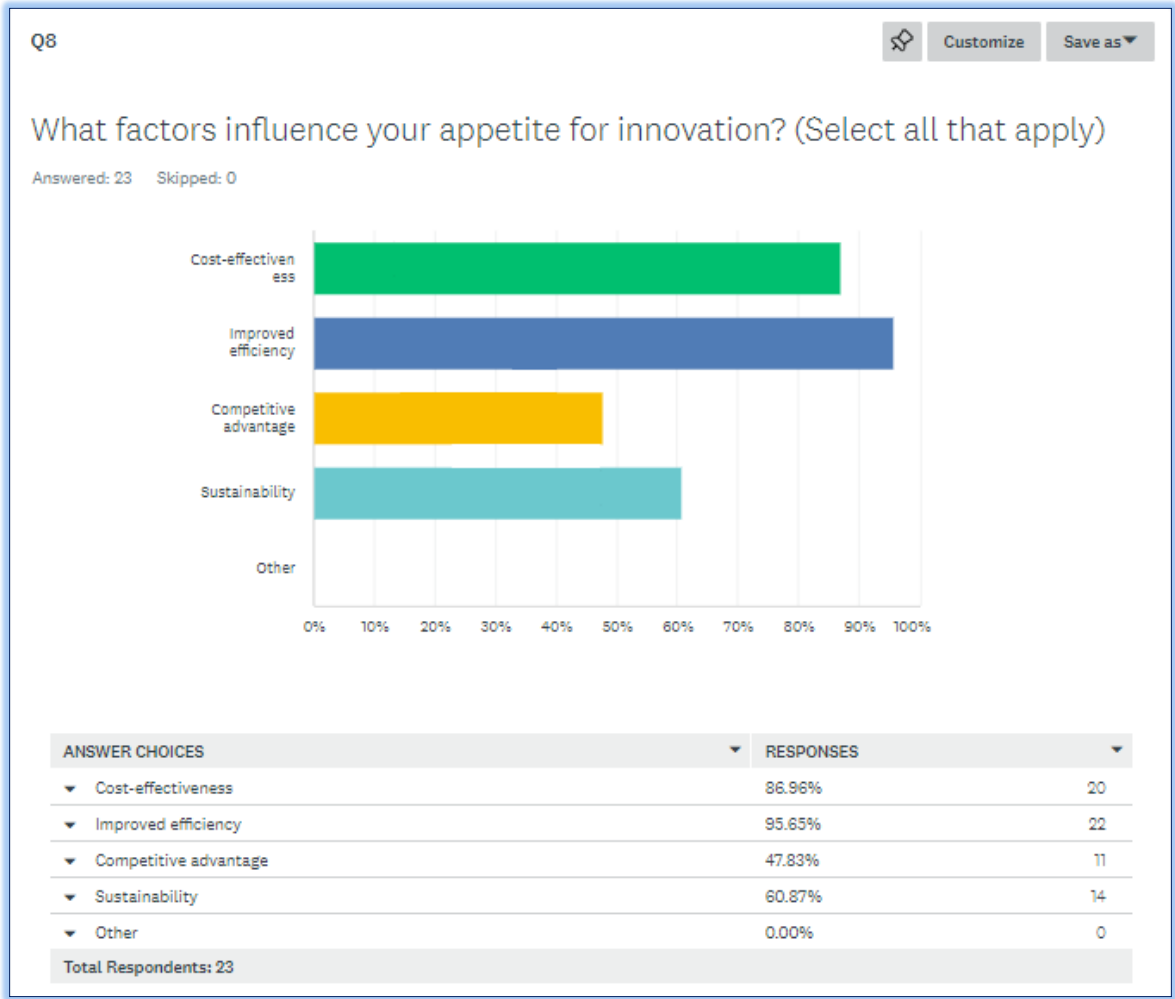


Figure 25. Factors that influence appetite for innovation. (SurveyMonkey. 2024)

Rank	Percentage	Number of Participants	Factor that Influences
1	96%	22	Improved Efficiency
2	87%	20	Cost effectiveness
3	61%	14	Sustainability
4	48%	11	Competitive advantage
5	0%	0	Other

Table 3. Factors that influence the appetite for innovation

Question 9

Q9

 Save as

What does your current business manufacture?

Answered: 22 Skipped: 1

RESPONSES (22)

 WORD CLOUD

 TAGS (0)

 Sentiments: OFF 

 Search Responses

 Filter: by tag

☐ Showing 22 responses

☐ PVCu windows and doors and GRP composite doors.
18/01/2024 12:19

[View respondent's answers](#) [Add tags](#)

☐ Cosmetics
16/01/2024 08:13

[View respondent's answers](#) [Add tags](#)

☐ Pvcu windows and doors
13/01/2024 14:16

[View respondent's answers](#) [Add tags](#)

Figure 26. What your current business manufactures (SurveyMonkey. 2024)

- This information is recorded in the survey participants table at the start of this section.

Question 10

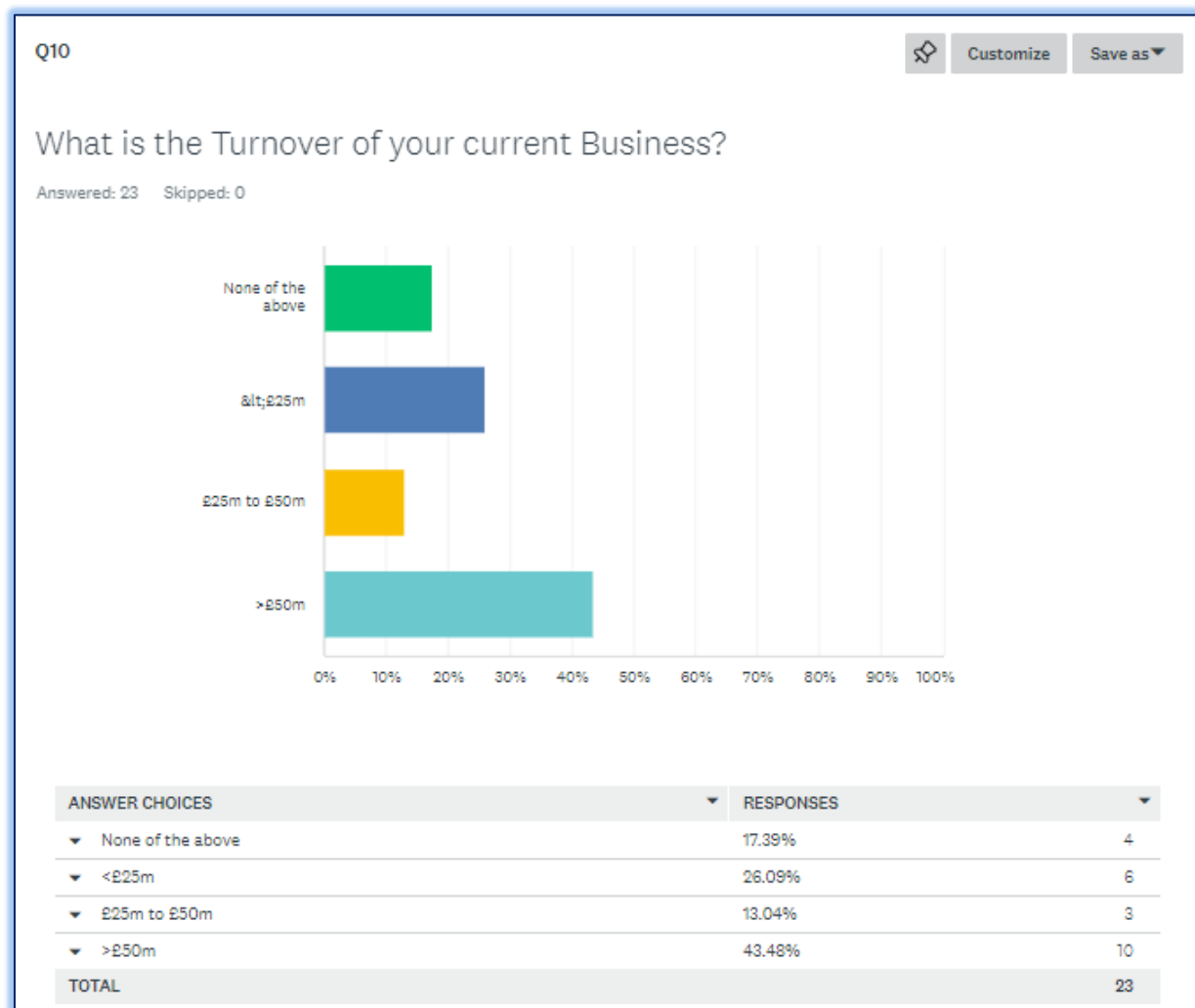


Figure 27. Turnover of your current business (SurveyMonkey. 2024)

- The majority have Turnovers larger than £50m.

5.2. End User Survey Discussion

The survey was designed to assess the awareness and usage of Industry 4.0 technologies, in particular Low Power Wide Area Networks.

The results indicate that the Awareness of Industry 4.0 is low with less than half the participants being aware. The usage of Industry 4.0 was even lower at 35%, indicating that the technologies have not been adopted. The correlation between the two could be that if there is limited awareness, then there will be limited application of the technologies.

The responses for the Applications of Industry 4.0 technology showed that some of the technologies were known to

over 60% of the participants. Cloud Computing, Artificial Intelligence (both 65%) and Virtual Reality (43%) were the Top 3 known to the group, with Smart Manufacturing and Additive Manufacturing the next 2 most popular for awareness. These results highlight that the awareness of some of the isolated technologies is higher than that of Industry 4.0 as a theme.

Two conclusions can be formed from this. Firstly, the technology is known, but not associated with Industry 4.0, indicating that the popular technologies are well known, but not as an Industry 4.0 technology. Secondly, these applications with higher awareness are also prevalent in the personal domain. Cloud computing, artificial intelligence and virtual reality are not limited to industrial applications with all three very popular in participants personal lives. Google Drive is a form of Cloud Computing, using the Cloud to store data, (Google, 2024) Artificial Intelligence (A.I.) is heavily discussed in the media, with articles regularly referencing A.I. applications such as ChatGPT and DALL-E, which are examples of generative A.I. which can learn from vast quantities of data and generate new content which feels like it was made by a human. (McCallum, S., 2023) Virtual Reality is popular with games console users, with many versions such as the PlayStation VR2 Virtual Reality headset being used for games such as Horizon Call of the Mountain. (Sony, 2024)

This conclusion is supported by Question 4 – applications of Industry 4.0 technology that are used in the workplace. Cloud Computing is 52% used in the participants' workplaces, most likely for cloud storage. A.I. is only being used in 1 participant's workplace and there is no use of Virtual Reality. Question 4 does display that there is low usage of Industry 4.0 technologies in the workplaces. 30% of the workplaces use None of the applications, only 26% using Industrial IoT and 21% using Smart manufacturing and Cyber-physical systems. An unexpected result was Additive Manufacturing at 17%, with the Author having experience of 3D printing in 3 separate workplaces over the last 6 years.

LPWAN was referenced in Question 5 and 6, with 10 of the participants aware of the technology (which does develop an inaccuracy of the survey – question 3 indicated only 3 participants were aware of LPWAN). 43% of the people being aware then translates to only 4 (17%) using the technology.

Questions 7 and 8 refer to Innovation, with all responses showing that Innovation is very or extremely important, to improve efficiency, be more cost effective and for sustainability purposes.

Questions 9 and 10 are generic to capture what industries are involved in the survey, and the Turnover of the businesses in the survey. Turnover is varied, and the wide scope of industries highlights low awareness and use of Industry 4.0 over many industries.

5.3. End User Survey Conclusion

This survey of 23 end users has provided a good insight to the awareness and use of Industry 4.0, LPWAN and aptitude for Innovation.

Industry 4.0 awareness is below 50%, but the awareness of singular technologies is over 60%, possibly due to non-industrial applications, such as Google Drive, Chat GPT and PlayStation VR headsets. Industry 4.0 usage is low, with only Cloud Computing achieving over 50%. The survey indicates that Industry 4.0 knowledge has not been spread to manufacturing business in the South Wales and Southwest England areas, resulting in low usage.

LPWAN awareness is less than 50%, with only 17% usage. This intimates that it is not adopted in the South Wales and Southwest England areas. With LPWAN more of an industrial technology the awareness has not been achieved in the personal lives of those in the survey.

Innovation is very/extremely important to improve efficiency, costs, and sustainability of a business. This outlook is encouraging and shows there is potential that improvements could be made using Industry 4.0 technology, if businesses were made aware of the technology, how to use it, and its benefits.

6. Chapter 6 - Practical Case Study

6.1. Case Study - Fillcare Ltd – Predictive Maintenance (Pd.M.) pilot

Fillcare Ltd have suffered with failures on its water chiller pumps for the last 10 years. A solution was required to introduce Condition Based Monitoring (C.B.M.) to monitor the condition of the pumps in place. The condition that would be analysed is vibration, by means of Vibration Analysis. *(Tauseef, 2024)*

Machines are made of moving parts that generate vibration which can be analysed with vibration analysis. A rotating device contains bearings, which are lubricated with grease. A standard vibration level is recorded via an accelerometer and used to form a trend. If the vibration level increases this could indicate deterioration, or a lubrication level too low for the bearing. The operator can use the vibration trend to trigger an action, such as greasing the bearing, or replacing the item. It is a form of predictive maintenance, to prevent premature failure of equipment. *(Ghazali, Mohamad, Hazwan, Mohd, 2021)*

A technology partner was engaged to introduce a remote C.B.M. solution. The Chiller pumps are located away from central engineering facility in various locations, some up to 500m away. This distance factor could increase costs of a hard-wired sensor network, so a wireless network was the priority. The chosen technology partner 'WhatsInIt' is a company that specialises in Artificial Intelligence (A.I.) based Predictive Maintenance. Self-proclaimed as a 'start-up' company consisting of a small team of 2, they have the agility to tailor bespoke solutions to meet customer requirements. *(WhatsInIt, 2022)*

The main scope was to have a remote CBM network installed at Fillcare to predict the pump condition. An addition specification was to use a LoRaWAN communication network for the Condition Monitoring devices to feedback data.

WhatsInIt solution

BoB Assistant Sensor

The BoB Assistant, developed by Watteco is a wireless IoT device that alerts in real time on the operating status of equipment containing rotating devices. It transmits data using a LoRaWAN network and applies an A.I. analysis algorithm embedded in its sensor to understand and monitor equipment. It detects and monitors vibration and temperature, but only vibration is required for the trial stage. *(Watteco, 2024)*

It has two distinct operating modes:

- Learning and reporting: The first 1-2 weeks is for calibration - it collects data from the host machine, learns from it and adjusts various settings.

- **Monitoring:** Regular mode, where it sends alarms if the vibration drifts (more than 25% but can be configured). It also produces periodic reports on machine health (vibration drift percentage, operating time, and anomaly). (Watteco, 2024)

The Sensor BoB 1.1 contains a 3-axis accelerometer and autonomous learning and reporting by Artificial Intelligence embedded by Cartesiam.



Figure 27. BoB Assistant 1.1 sensor (Tauseef, 2024)

Milesight Gateway

The BoB Assistant communicates with a Milesight UG65 LoRaWAN gateway. The UG65 can connect to devices up to 2km in urban areas and can support up to two thousand end devices. It can connect to both 4G and Wi-Fi. (Milesight, 2024) In this case a 4G sim card is used for connectivity to the cloud network where the dashboard collates and presents the data.



Figure 28. Milesight Gateway (Tauseef, 2024)

Alliot Technologies Dashboard

The sensor required data collection for 2 weeks, to learn the normal running feedback and collate a baseline trend. The

cloud platform is hosted by Alliot technologies, an IoT solutions company. (Alliot Technologies, 2024) The BoB Assistant which transmits a sample every 3 hours.

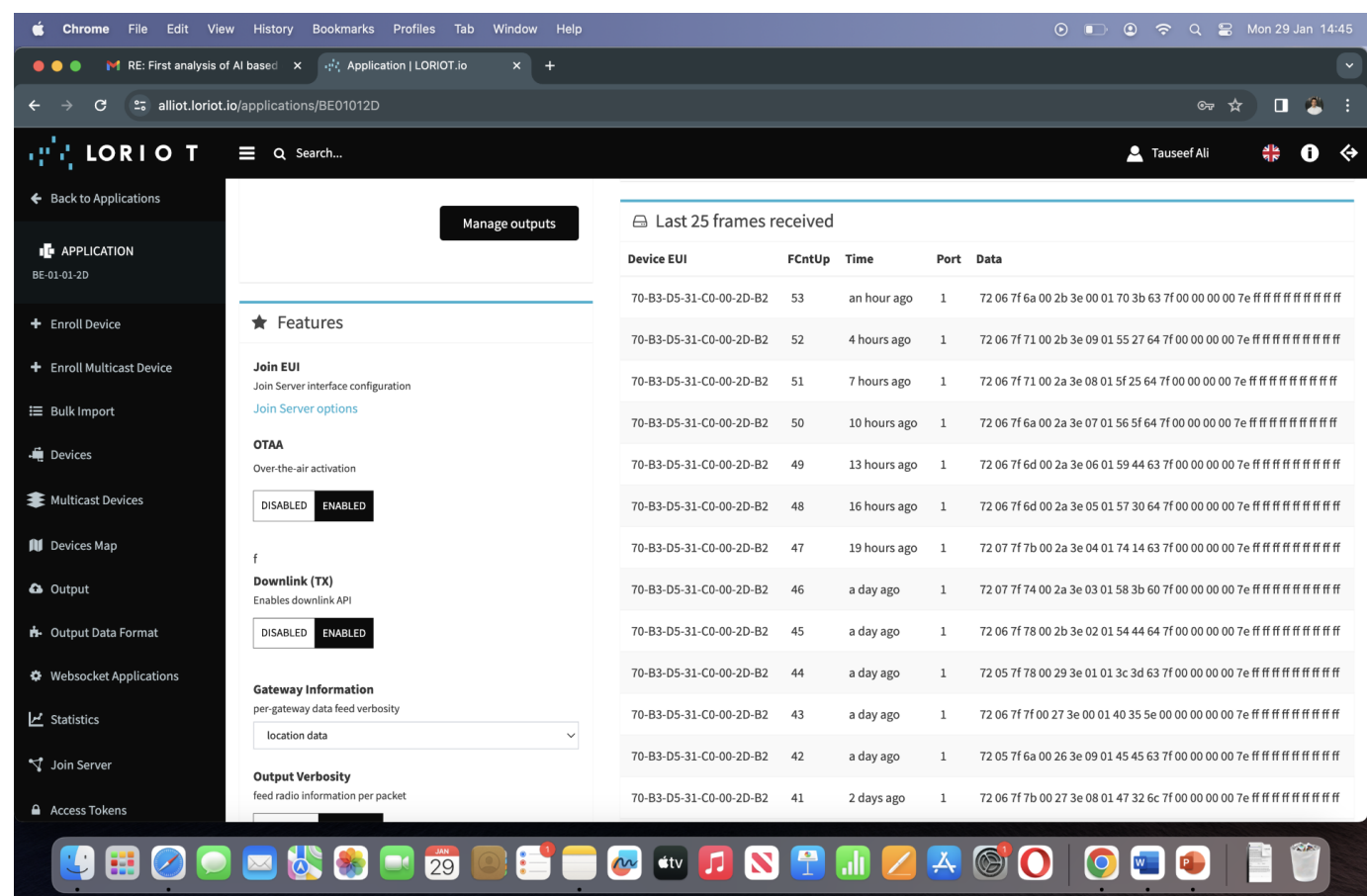


Figure 29. Alliot IoT platform (Tauseef, 2024)

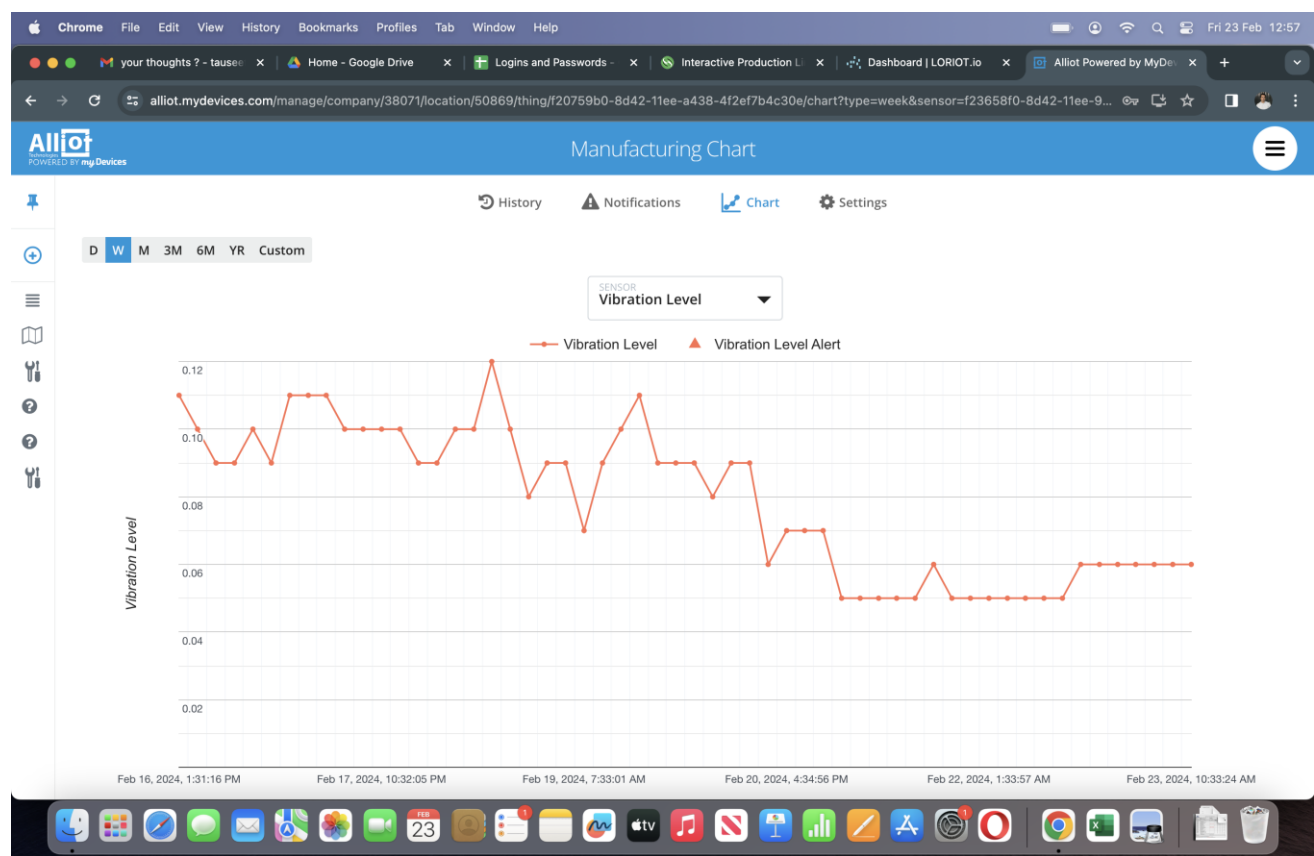


Figure 30. Trend platform (Tauseef, 2024)

The plan is to trend and analyse the function of the one sensor and if satisfactory expand to further applications across the site, with sensor distances ranging from 20 metres to 500 metres.

This is a proof of concept for the technology A.I. abilities, and the LoRaWAN reliability with the trial planned for 3 months before more devices are applied.

6.2. Case Study Discussion

The case study is an opportunity to evaluate the ease of implementation, availability, and function of the technology.

Fillcare are using a technology partner for this with the agreement that this would be a pilot project, free of charge for the first device. Ali Tauseef from WhatsInt installed the BoB Assistant device magnetically to a Chiller Pump. It is IP68 rated making it capable in all weather conditions which makes it suitable for the Chiller Pump, which is located externally.



Figure 31. Chiller pump with BoB sensor installed (Tauseef, 2024)

BoB Assistant was developed and supplied by a French company Watteco. WhatsInt sourced the devices via an internet shop. If Fillcare required a second device then an indicative cost would be £682.11. (Watteco, 2024)



Education ▾ Industry Solutions ▾ Use Cases ▾ Products ▾ Services

Home » Shop » Industrial Vibration Sensor



Industrial Vibration Sensor

£682.11

The BOB Assistant industrial vibration sensor is specially designed for smart machine monitoring.

1

Add to Quote

SKU: 50-80-001 Categories:

Figure 32. BoB Assistant sensor cost (Alliot Technologies, 2024)

The system updates the cloud dashboard accurately every 3 hours, an interval that allows a longer battery life. The BoB Assistant also has a 48-hour memory, which mitigates network communication issues.

Alternatives

Two other technology partners were initially engaged to propose a solution for the diagnosis of Fillcare Ltd.'s Chiller pumps. Both with the same scope – Remote Condition Based Monitoring which could be monitored on a cloud platform.

JPS Reliability

JPS Reliability proposed a remote Condition Based Monitoring solution using Kappa X wireless sensors, produced by Sensotek, supported by Reliability Maintenance Solutions (RMS). The Kappa X sensors transmit data to a central Sensotek Gateway using an ISM radio band. An ISM radio band is a radio frequency band operating on frequencies reserved for industrial, scientific and medical use. These frequencies are prone to interference from other devices operating in this radio frequency band. (RMS Ltd, 2023) (Ofcom, 2022)

JPS specify and install the Kappa X sensors on the required equipment. The sensors transmit data every minute to the Kappa X gateway, which communicates the data via Wi-Fi or a cellular connection to the Sensotek cloud network. Sensotek host a cloud platform which displays the feedback data in graphical trend form to allow easy analysis for the equipment being monitored. It can be linked to Sensotek Analytix or A.I. development software that can analyse the

data further and develop feedback specified by the customer. *(RMS Ltd, 2023)*

A benchmark case study was presented to highlight an application where JPS had previously used this system. The application was in a Plasterboard factory, with the system being used to monitor circulation fan motors installed on a plasterboard drying oven. It indicated a range of 89m was achieved for sensor to gateway communication. The Case study is also used by RMS Reliability on its website as a sample. *(RMS Ltd, 2023)*

Hayley Group

Drive Management Services (DMS) is part of the Hayley group and implements Condition Monitoring solutions. *(Findlow, 2023)* DMS offered a solution using BluVib vibration sensors that transmit data to a gateway using Bluetooth 5 low power wireless communication. The sensors are made by Sensor-works, who also produce compatible gateways to receive the data and transmit to a local ethernet network or directly to the cloud using wi-fi or cellular networks. *(Sensor-works, 2023)*

Hayley presented a case study based on a Quarry application using the DMS Machine Guard Asset Minder system, featuring Bluetooth accelerometers and gateways alongside the AssetMinder IoT platform. 33 BluVib sensors were connected to vibratory screen applications, transmitting to AssetMinder for analysis. The data was displayed on a cloud platform for remote access, and alarms configured to alert any anomalies in the trended data. *(Hayley, 2022)(Sensor-works, 2023)*

6.3. Case Study Conclusion

The practical case study is a required solution. Pump failures at Fillcare required a predictive maintenance solution. A standard wired system would normally be considered, but LoRaWAN enabled devices was presented by WhatsInt as an alternative. The technology partner was granted the project due to the proposal of Industry 4.0 technologies – Artificial Intelligence and LoRaWAN to enhance Predictive Maintenance. It was also a free of charge pilot; with the case study initiated in January 2024.

The project functions, and proves the technology is suitable for the application. Adoption of the Industry 4.0 technology is positive in this situation. The next step is to assess the costs of the sensors, an example cost of £682 per BoB Assistant sensor. *(Alliot Technologies, 2024)* This will need comparison to alternative technology to indicate whether there are benefits to using this system, instead of conventional wired, or cellular wireless solutions. Another factor to decide whether this succeeds is the knowledge gap for Fillcare personnel. Specialised technology partners are required to implement LoRaWAN technology, whilst conventional Vibration Monitoring equipment can be implemented by general engineering solution providers such as Hayley Group Ltd. The expectation is for the Technology partner to transfer knowledge to Fillcare personnel to manage as a long-term solution.

The alternative solutions would both have met the scope of the project – Remote Condition monitoring, but Fillcare chose WhatsInt's solution due to the wide range required for the sensor network. The Fillcare pumps can be over 500m

apart, which can be achieved with a LoRaWAN network. The other factor was the experimental interest of the site Head of Engineering, who was fully aware of the LoRaWAN technology, wanting to trial an Industry 4.0 technology.

If the current Head of Engineering was not employed by Fillcare at the time of the trial then the Hayleys solution would have been selected, because of a company relationship with Hayley Group Ltd.

Both JPS and Hayley offered different technologies for wireless data transmission - Bluetooth and ISM radio frequency. Along with LoRaWAN this brings 3 different types of wireless communications offered over 3 proposals. This indicates that there is not a preferred communication type for remote CBM when the proposals were discussed in 2023.

7. Chapter 7 - Discussion

7.1. Introduction

Industry 4.0 has been available for over a decade in a variety of technologies, providing numerous benefits. This report has introduced some of the technologies available, and their uses across the world. Industry 4.0 in UK manufacturing has been reviewed, giving focus on government commitments to digitalisation and Industrial Digital technologies, with comparisons to adoption in other developed countries.

LPWAN technologies have been introduced, focussing on 3 of the most common protocols in use. Global use and UK adoption has been referenced, with case studies reviewed to highlight use cases and benefits.

To engage UK manufacturing adoption Interviews with Industrial suppliers of technology, and surveys with end users have been carried out to gauge the actual adoption of local UK manufacturers.

Finally, a live case study has been piloted to trial a LoRaWAN solution to determine the benefits of the technology, and whether adoption will be successful.

7.2. Research Findings

This research has highlighted that there are numerous Industry 4.0 technologies, which deliver many solutions to businesses in various ways - from large scale applications using a collection of technologies such as Smart factories, Smart cities and Smart buildings, to single technology applications such as Pallet tracking and Predictive Maintenance.

Industry 4.0 in UK manufacturing was reviewed, with the UK determined as the 8th largest manufacturing economy by value of output in 2023 and classified as a leader in technology development. Despite this, the adoption of Industry 4.0 or Industrial Digital Technologies has been slow, with only 50% of UK companies actively working on Industry 4.0 solutions. (*RSM International Ltd, 2024*)

One of the factors that may have caused the slow adoption is Costs, with manufacturers expecting lower profit margins in 2024. Economic instability has reduced investment in the private sector, which has been caused by Brexit, Covid, and supply chain disruptions due to the war in Ukraine and other environmental and geopolitical disruptions. (*MakeUK, 2024*)

Lack of expertise and execution support is a defined factor – if companies do not have the skills or resource to implement Industry 4.0 then engagement will be low, having to rely on technology partners if available.

The Government's role in technology innovation is key to UK manufacturing. Other major economies have long term strategies, with the UK slow to implement initiatives to the whole of the UK. The 'Made Smarter' Initiative, supported by

the government, has only recently been rolled out to the whole of England, but not reaching out to Wales, Scotland and Ireland until 2026. (Gov.UK.,2023) The spotlight research on Wales indicated low adoption across most Industrial Digital Technologies and if the UK Government are not focussing on Wales until 2026 this may possibly hinder Welsh manufacturing.

Although slower to engage compared to other developed countries, research shows that the UK Government have committed UK strategies such as the *UK's International Technology Strategy* and committed more funding via Made Smarter and other institutions to collaborate and engage with UK manufacturers to offer technology solutions and pathways to digitalisation. (Gov.UK, 2023)

LPWAN research highlights LoRaWAN as the dominant protocol, and widely used across the world. An unlicensed network protocol it is being delivered by Technology partners and specialist, as well as community network solutions such as The Things Network. (*The Things Industries, 2024*)

NB-IoT is a licensed LPWAN protocol, which has engaged network operators such as Vodafone, BT and O2 to support their 5G networks, suggesting uses in areas where 5G is unreliable for IoT projects, such as energy monitoring and smart building solutions. (*Vodafone Limited, 2024*)

Globally LPWAN is being driven by governments, with examples in India and China referenced, for energy monitoring and Smart Grids. In the UK technology partners are driving adoption, collaborating with large businesses such as Anglian Water and Yorkshire Water to deliver LPWAN network solutions for water metering, and Predictive Maintenance solutions. (*Beecham Research & LoRa Alliance, 2023*). Case studies and market analysis has suggested that the most popular applications for LPWAN technology is Smart Buildings and Smart Energy solutions.

To support the opinion that Industry 4.0 adoption in the UK is slow, LPWAN technology is a government focus in developed countries across the world. In the UK multi-national technology partners such as Heliot, Connexion and Vodafone are driving LPWAN adoption in UK businesses.

The majority of the research has focussed on countries, markets and multi-national businesses, so further research with more local Industrial service providers was completed. Interviews discussing Industry 4.0 and LPWAN awareness and adoption were conducted with varied results. Industry 4.0 awareness was high, but to varying degrees, with implementation only conducted in large multinational companies such as Nestle and Tata. A representative from Schneider stating that despite marketing Industry 4.0 for 10 years it is only recently seeing adoption. (*Wallace, 2024*). LPWAN awareness was low, and adoption also low. A 'hobbyist' had a personal LoRaWAN network via a community driven forum, with the other example of adoption being a sitewide network in Tata Steel in Port Talbot. The Tata Steel implementation assisted by a SIEMENS technology partner. Both Tata Steel and SIEMENS being large Multinational companies. (*Parmley Graham Ltd, 2024*) An opinion that there was too much variety of technology and other options such as 4G may hinder adoption of LPWAN technology, was referenced by some of the participants. (*Faulkner, 2023*) (*Wallace, 2024*) (*McCallum D., 2024*)

To further explore adoption End Users were engaged in a survey to collate awareness and usage statistics. A wide span of industries was involved in various parts of Southwest England and Wales. With Industry 4.0 awareness less than 50%, and LPWAN awareness lower than 20% the survey indicated that the knowledge and skills had not reached End Users.

Cloud Computing was the highest used Industry 4.0 technology. Nearly all participants agreed that Innovation was extremely or very important, showing they were open to new ideas to improve efficiency and cost effectiveness.

The last research item is a live case study courtesy of Fillcare Ltd and WhatsInt. Simulating the example of Connexion collaborating with Anglian Water to deliver a Predictive Maintenance Solution, Fillcare Ltd engaged with WhatsInt to pilot a similar solution. The study is to prove the concept of LoRaWAN capability and ease of implementation. Cost of devices are high, so wider adoption will need to be assessed (*Tauseef, 2024*)

8. Chapter 8 - Conclusion

8.1. Conclusion

This research project has presented the conclusion that Industry 4.0 has not been a focus in the UK in comparison to other developed countries. Low adoption is due to Economic, Social and Political challenges. Multi-national companies such as Audi have the resources to develop Smart Factories and gain the associated benefits. Smaller UK Manufacturing businesses have less disposable income to invest in large scale technological innovations at the same scale. Recent economic stability has limited investment, with some companies expecting reduced revenue in 2024 due to increasing wages and energy costs. Industry 4.0 technologies can give savings in both areas, with Automation and Smart buildings, but the lack of awareness and skills hinders these solutions.

Recent UK Government Initiatives have been launched and widened but it seems that end users in UK Manufacturing still do not have access to the resources available to implement Industry 4.0 technologies. The Made Smarter programme is a government backed programme to support businesses learn and adopt innovative technology, but only covers England. (*Made Smarter, 2024*) The slow rollout of Made Smarter to Wales and the spotlight on Wales 4.0 exposes a low adoption rate already, so the delay in support may reduce engagement in Industry 4.0. (*Welsh Government, 2023*) Wales must rely on Academic Institutional support, such as the Advanced Manufacturing Research Centre (AMRC) and University of Wales Trinity St David (UWTSD) who collaborate with local businesses to help with Industrial Digital Technology. (*AMRC, 2024*)

Collaborative partnerships can improve adoption of Industry 4.0. A variety of case studies involve technology experts and network providers working with businesses to implement Industry 4.0 solutions. These technology partners may also have better access to funding, for example, four Local Policy Innovation Partnerships (LPIPs) will share £20 million in funding from UK Research and Innovation (UKRI), Economic and Social Research Council (ESRC), the Arts and Humanities Research Council (AHRC) and Innovate UK. One of the LPIPs is a project in Wales, which will develop an inclusive, sustainable rural economy by giving local government, business and communities the evidence they need to make decisions that build prosperity and reduce inequality by addressing data gaps and improving data access in rural areas. (*UKRI, 2024*)

The same conclusion applies to Low Power Wide Area Network (LPWAN) technology. Focussing on a particular Industry 4.0 technology has given validation to the findings. Researching this technology example has shown low awareness, and a lack of strategy to provide the focus in the UK, compared to other developed countries. Partnerships between technology provider and businesses has been the most successful method of adoption and implementation. Further investigation highlighted that LPWAN is used in conjunction with 5G cellular networks, and 5G empowered devices. Network operator engagement with NB-IoT to enhance 5G networks should ensure a longer-term use for LPWAN protocols. (*Vodafone Limited, 2021*)

Power Wide Area Networks (LPWANs) due to the variety of technologies, and potential alternatives. For example, Sensor Works are releasing a 5G Vibration sensor, which will supersede its Bluetooth BluVib sensor that is currently being offered for the practical case study. (*Futurescot, 2023*) If the BluVib sensors had been chosen for the practical trial, via Hayleys, they may be obsolete. End user engagement will be hampered by this rapidly changing approach. Learning BluVib sensor technology may be pointless, so would they learn about the 5G sensors when they could be superseded in a short space of time?

Industry 4.0 technologies have the potential to benefit UK Manufacturing, but the long-term benefits are not being realised because of a slow rate of adoption. The benefits of Industry 4.0 clearly define it as the solution to improve UK manufacturing, but the challenges inhibit its progress. The Government, institutions, businesses and end users need to engage with Industrial Digital Technologies to improve business performance and keep pace with other developed countries. The below Schwab quote summarises the findings of this report, with the current challenges hindering the embrace of the technological innovation:

“Still valid today is the lesson from the first industrial revolution – that the extent to which society embraces technological innovation is a major determinant of progress. The government and public institutions, as well as the private sector, need to do their part, but it is also essential that citizens see the long-term benefits” (*Schwab, 2017a*)

8.2. Recommendations

Large multinational companies have more access for funding, technical expertise, and resources to deploy industry 4.0. Smaller UK manufacturers may not have the same access. Funding via partnerships, such as UKRI and Digital Catapult can be applied for, but businesses may need assistance in building correct propositions. Partnering with academic partners such as AMRC may be the solution to explore.

The UK government has published various strategies to progress the digitalisation of UK manufacturing. This needs to be followed with funding, and tax incentives to enable businesses to invest in Industrial Digital Technologies. (*MakeUK, 2024a*)

Education of Industry 4.0 is required. Funded training initiatives, such as MADE (Manufacture Advanced Design Engineering) Cymru are required that provide training and support to the manufacturing sector with accredited courses and R&D courses. EU funding (via Welsh Government) supported the MADE Cymru initiative which had over 400 students involved in courses such as ‘Introduction to Industry 4.0’ and ‘Design for Industry 4.0’, whilst partnering with over 140 businesses to support and guide improvements. (*MADE Cymru, 2024*)

Further opportunities can be developed with local technology partners. For example, Control2k offers business services such as technical training and technical support to businesses with reference to systems integrations, including an Industry 4.0 platform, the Industweb Data Integration Platform. A small technology partner, having worked directly with the UKRI and Made Smarter, can access further funding, resources and technical solutions to deliver projects for businesses. (*Control2k, 2024*)

A validation recommendation is to repeat this research in 2025, to assess the rate of change for Industry 4.0 adoption and to review the UK Government strategy. The Made Smarter expansion may deliver positive change and it would be valuable to capture the change one year after implementation. The practical case study pilot at Fillcare should also be reviewed to assess whether the LoRaWAN solution was fully implemented.

8.3. Limitations

This research paper incorporated interviews and surveys for participants based mainly in the Southwest England and Wales areas. To widen the scope of the research other areas of the UK can be engaged, especially the Northwest of England, where the Made Smarter has been piloting a £20million scheme to drive digital technology among SMEs since 2019. (*Made Smarter, 2024*)

With technology evolving swiftly there are new innovations being explored. This paper is based on Industry 4.0, but Industry 5.0 is already being discussed, focussing on human-centric interactions to complement Industry 4.0 technology. (*Garrido et al, 2024*) Similarly, LPWAN may not be sustainable if the 5G network becomes reliable in remote or currently unreliable areas and requires less power.

This research could incorporate further Industry 4.0 technologies to evaluate the trends in adoption, and whether certain technologies are more popular than others. Limiting research to LPWAN may have provided a narrow view of Industry 4.0 adoption.

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10. Appendix

10.1. Appendix A - Research Interviews – Industrial Service Providers

Mark Clifton – Managing Director - Castle Control Solutions Ltd – Automation

Are you aware of Industry 4.0 technology?	<i>I am aware of the technology, in reference to 'Industry 4.0 ready.' I have not directly been involved in any Industry 4.0 projects. (Clifton, 2024)</i>
In your opinion, has Industry 4.0 been adopted amongst your customers?	<i>If Industry 4.0 refers to wireless systems, then yes - customers are looking to develop Supervisory Control and Data Acquisition (SCADA) systems and requesting wireless options. Wireless options are mainly wi-fi, or 4G/5G Sim based wireless communications.(Clifton, 2024)</i>
Are you aware of Low Power Wide Area Networks (LPWAN)?	<i>No</i>
In your opinion, has LPWAN been adopted amongst your customers?	<i>No</i>

David McCallum – Area Sales Manager - Templegate Electrical Supplies

Are you aware of Industry 4.0 technology?	<i>I am aware of Industry 4.0. References were made in a recent master's degree in Renewable Energy. (McCallum, D., 2024)</i>
In your opinion, has Industry 4.0 been adopted amongst your customers?	<i>No, customers are not requesting the technologies associated with Industry 4.0. Many of my current suppliers operate within the controls and automation sector, supply sensors and basic controls that allow for a level of automation within certain sectors, i.e. safety relays, sensors and NO/NC contacts. Industry 4.0 technology is not really discussed with them.</i> <i>I would say in my experience and opinion, cost, lack of skills and experience within the industry 4.0 sector/ revolution including the social and economic effects are affecting the progression. (McCallum, D., 2024)</i>
Are you aware of Low Power Wide Area Networks (LPWAN)?	<i>No</i>
In your opinion, has LPWAN been adopted amongst your customers?	<i>No</i>

Tony Dobbs - Service and Training Director – Industrial Automation & Control Limited (IAC)

Are you aware of Industry 4.0 technology?	Yes, we assist designs of networks and integration of IoT hardware. IAC currently use cloud computing and Smart sensors for various projects. (Dobbs, 2024)
In your opinion, has Industry 4.0 been adopted amongst your customers?	Our customers are requesting designs including Industry 4.0 technology such as cloud computing and smart sensors. (Dobbs, 2024)
Are you aware of Low Power Wide Area Networks (LPWAN)?	Yes
In your opinion, has LPWAN been adopted amongst your customers?	Yes, we have assisted design of LPWAN networks. (Dobbs, 2024)

Mark Harrison – Business Development Manager – Process Control Services (PCS) UK Ltd – Electrical Contracting Services

Are you aware of Industry 4.0 technology?	Yes
In your opinion, has Industry 4.0 been adopted amongst your customers?	We are starting to get more involved with Industry 4 via our customer Nestle in Carlisle. The main Automation areas that we work with are: PLCs, HMIs, SCADAs for the market leading automation solutions (Siemens, Allen Bradley, and Mitsubishi). Communications between Modbus/Profibus/Ethernet/Profinet/Fibre Remote Service Support – Secure remote VPN Connection to streamline software issues on site and do software updates. Ewon is a common gateway for remote connections. (Harrison, 2024)
Are you aware of Low Power Wide Area Networks (LPWAN)?	Yes
In your opinion, has LPWAN been adopted amongst your customers?	No

Mike Faulkner – Network Manager, IT Architect - UK Windows and Doors Group Ltd

Are you aware of Industry 4.0 technology?	Yes
In your opinion, has Industry 4.0 been adopted amongst your customers?	No, limited scope for the technologies with other priorities such as obsolescence, data integrity and lifecycle issues. Financial constraints mean that risk mitigation is the priority. For example, we have servers running magnetic hard drives. Our focus is to upgrade to solid state hard drives. Cloud servers have been explored

	<i>as a project, but we don't have the manpower to prepare the data, or the finances to outsource it fully. (Faulkner, 2023)</i>
Are you aware of Low Power Wide Area Networks (LPWAN)?	<i>Yes, specifically LoRaWAN. I use a LoRaWAN gateway in my home, hosting local LoRaWAN networks for building sites and local businesses. I earn money for hosting LoRaWAN in my area, with local companies able to access my gateway within a few miles. It saves them setting up a permanent network, or being charged for Cellular network access (4G/5G). I get paid by a data sharing hosting site, with higher income for higher data volume that travels through my gateway. (Faulkner, 2023)</i>
In your opinion, has LPWAN been adopted amongst your customers?	<i>As a hobbyist in the field, I will focus on LoRaWAN and I could think of several reasons why LoRaWAN hasn't taken off in the UK.</i> <i>Limited Coverage: LoRaWAN networks require a sufficient number of gateways to provide coverage. In some regions, the infrastructure for LoRaWAN networks may be limited or not yet fully developed, which could impact the adoption of this technology. The coverage availability may have been a factor in the slower adoption of LoRaWAN in the UK.</i> <i>Competing Technologies: The UK has seen the deployment of various IoT connectivity options, such as cellular-based networks like NB-IoT (Narrowband IoT) and LTE-M (Long-Term Evolution for Machines). These technologies provide different advantages and use cases compared to LoRaWAN, and their availability and promotion could have influenced the adoption landscape.</i> <i>Market Awareness and Education: The adoption of any new technology often requires awareness and understanding among potential users. The awareness and education about LoRaWAN may not have reached a critical mass in the UK, limiting its adoption. Market awareness initiatives and educational efforts by network operators and IoT solution providers can play a crucial role in driving adoption.</i> <i>Industry Focus: The focus of industries and businesses in the UK may have been more inclined toward other wireless technologies or connectivity options for their IoT applications. Depending on the specific needs and requirements of different sectors, alternative technologies may have been preferred over LoRaWAN.</i> <i>Regulatory Factors: Regulatory frameworks and spectrum allocation policies can impact the adoption of IoT technologies. Changes or limitations in regulations related to wireless spectrum usage, licensing, or costs could influence the adoption of LoRaWAN or other IoT connectivity options. (Faulkner, 2023)</i>

Matthew Wallace - Digital Sales Director UK&I - Digital Energy - Schneider Electric

Are you aware of Industry 4.0 technology?	<i>Yes, being in the Digital Energy sector Industry 4.0 is very prevalent in major projects we are working on. (Wallace, 2024)</i>
In your opinion, has Industry 4.0 been adopted amongst your customers?	<i>Probably one of the benefits of working for a manufacturer in that space is being at the forefront of the technology that enables the marketing language 'industry 4.0'. Whilst we've been talking about and influencing the market for 10+ years, adoption is only now beginning to ramp up with rapid requirement for retrofit technology to enable data visibility for action around energy reduction/sustainability agendas/goals etc. Energy monitoring using IoT technology is something we do pretty well within buildings, utilising protocols such as Zigbee, Ecocean, LoRaWAN and other mesh type wireless networks. Common one used is the Schneider PowerTag which is a wireless CT that we put on MCB's to monitor final circuit data and present alarms for out of tolerance behaviours etc. (Wallace, 2024)</i>
Are you aware of Low Power Wide Area Networks (LPWAN)?	<i>Yes</i>
In your opinion, has LPWAN been adopted amongst your customers?	<i>Not widespread. 4G sim cards also get deployed as they are pretty cheap compared to creating networks. The tech used generally depends on the level of resiliency you need in the network. If the energy data or any other data for that matter i.e. environmental data, is critical for audit purposes for quality or traceability of faults in certain highly regulated sectors then we wouldn't use wireless comms unless localised...wireless wide area networks just aren't robust enough to take the risk in lost data.</i> <i>Another challenge is when more and more wireless communications get used on varying bandwidths the chances of miscommunications and overlaps increases. Wireless is great but comes with pitfalls like anything else. (Wallace, 2024)</i>

Marc Lewis – External Sales Engineer – Parmley Graham Ltd

Are you aware of Industry 4.0 technology?	<i>Yes, Parmley Graham are aware of I4.0 and have been supporting our customers on their journeys for some time now. (Lewis, 2024)</i>
In your opinion, has Industry 4.0 been adopted amongst your customers?	<i>Yes, some have already adopted I4.0 in some form e.g. robotics and systems to acquire OEE data, automation of production lines.</i> <i>Parmley Graham invested in an I4.0 Centre which is based at our HQ in Gateshead.</i>

We are a SIEMENS industrial partner. SIEMENS are very focused on I4.0 and digitalisation. Our close association and partnership with them means we are as well

WAGO HMS and BANNER are other manufacturing partners who are starting to focus on I4.0. (Lewis, 2024)

Are you aware of Low Power Wide Area Networks (LPWAN)?

I am not aware of LPWAN. (Lewis, 2024)

In your opinion, has LPWAN been adopted amongst your customers?

I have had experience with LoRaWAN. TATA Steel in Port Talbot have recently added a LoRaWAN network to collect data from their production processes. (Lewis, 2024)

10.2. Appendix B - Research – End User Survey

Industry 4.0 and LPWAN Awareness and Usage Survey

1. Are you aware of Industry 4.0 technology revolution?

- ☐ Yes
- ☐ No

2. Do you currently use Industry 4.0 technology in your business or personal life?

- ☐ Yes
- ☐ No

3. Which applications of Industry 4.0 technology are you aware of?

- ☐ Smart manufacturing
- ☐ Industrial IoT (Smart/wireless devices)
- ☐ Cloud Computing (e.g. Cloud Servers)
- ☐ Cyber-physical systems (Autonomous Robotics)
- ☐ Additive Manufacturing (3D Printing)
- ☐ Artificial Intelligence
- ☐ Augmented Reality
- ☐ Virtual Reality

- ☐ Low Power Wide Area Networks
- ☐ Other
- ☐ None of the above
- ☐ Other (please specify)

4. Which applications of Industry 4.0 technology are used in your workplace?

- ☐ Smart manufacturing
- ☐ Industrial IoT (Smart/wireless devices)
- ☐ Cloud Computing (e.g. Cloud Servers)
- ☐ Cyber-physical systems
- ☐ Predictive maintenance
- ☐ Additive Manufacturing (3D Printing)
- ☐ Artificial Intelligence
- ☐ Augmented Reality
- ☐ Virtual Reality
- ☐ Low Power Wide Area Networks
- ☐ Other
- ☐ None of the above
- ☐ Other (please specify)

5. Are you aware of Low Power Wide Area Networks (LPWAN)?

- ☐ Yes
- ☐ No

6. Do you currently use LPWAN technology in your business or personal life?

- ☐ Yes
- ☐ No

7. How important do you think innovation is for the success of businesses today?

- ☐ Extremely important
- ☐ Very important
- ☐ Moderately important
- ☐ Slightly important
- ☐ Not important

8. Are you actively seeking innovative solutions for your business or personal projects?

- ☐ Yes
- ☐ No

9. What factors influence your appetite for innovation? (Select all that apply)

- ☐ Cost-effectiveness
- ☐ Improved efficiency
- ☐ Competitive advantage
- ☐ Sustainability
- ☐ Other

10. What does your current business manufacture?

11. What is the Turnover of your current business?

- ☐ <£25m
- ☐ £25m to £50m
- ☐ >£50m



Survey Link - <https://www.surveymonkey.com/r/LMD9DFG> (SurveyMonkey, 2024)