



Executive Briefing

5G'S IMPACT ON MANUFACTURING: \$740BN OF BENEFITS IN 2030

The unique benefits of 5G could unlock \$740bn of value in manufacturing in 2030. This is based on models generated from 100+ interviews and surveys with senior manufacturing industry executives. What steps should operators, manufacturers and others take to achieve these benefits?



Preface

The document has been prepared by independent consulting and research firm STL Partners. It is based on extensive research into the impact of 5G on industries and leveraged the output of an interview programme with telecoms and manufacturing industry representatives and a survey of 104 participants from manufacturers across developing and developed countries. The research programme has kindly been supported by Huawei.

This report should be read by manufacturers who are interested in using technology to enhance operations, particularly those responsible for operations and digitalisation: COOs, CEOs and CSOs. The content is also relevant to telecoms operators, namely CSOs, strategy executives, CMOs, and other ecosystem stakeholders: software/application vendors, cloud and edge computing companies, ISPs, systems integrators, developers and similar organisations.

Mentions of companies in this document are intended as illustrations of market evolution and are not intended as endorsements or product/service recommendations.

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STL Partners is continuously working to understand how 5G can benefit other industries and develop strategies for telecoms operators and other industries to accelerate the delivery of benefits. Should you like to learn more about this research and future projects or find out how we can help manufacturers and operators to work more effectively together and take advantage of 5G please contact us.

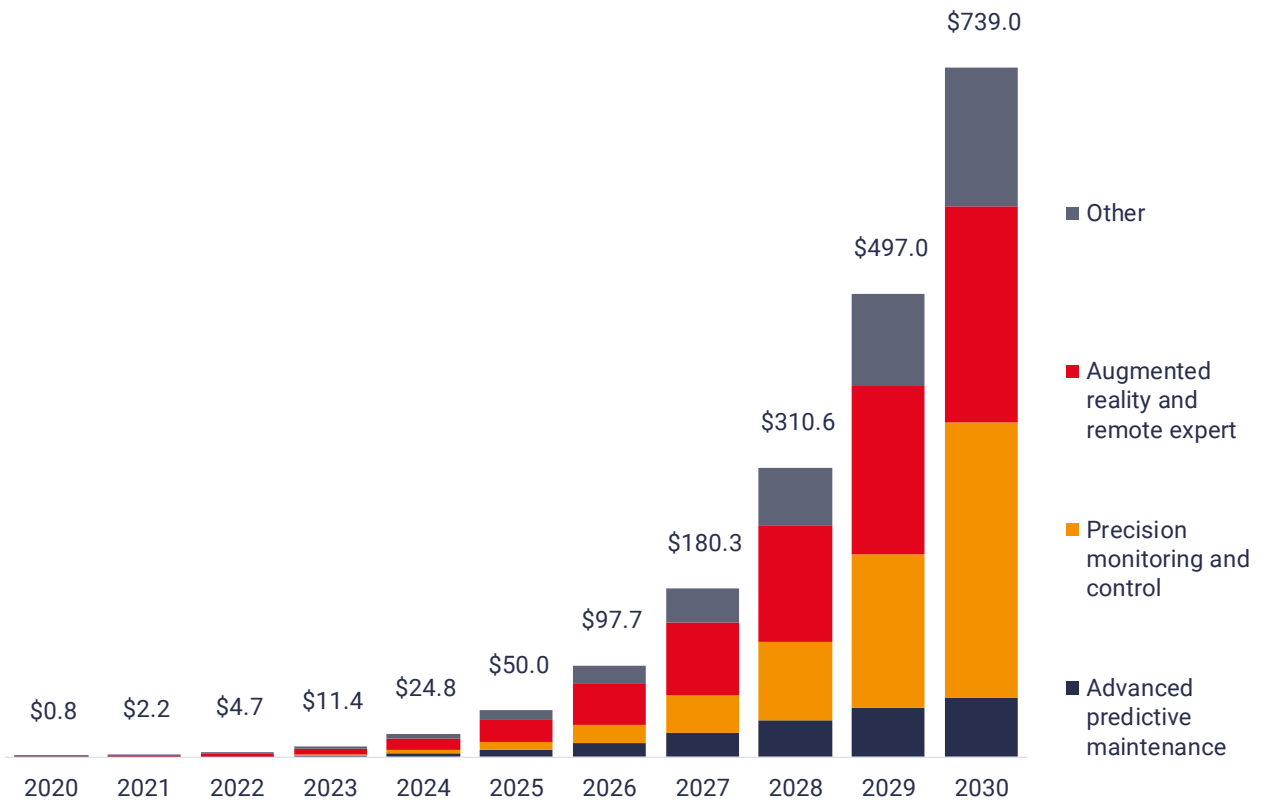
Other reports in this 5G series include:

- \$1.4Tn Of Benefits In 2030: 5G's Impact On Industry Verticals
- Curtailing Carbon Emissions: Can 5G Help?
- 5G's Healthcare Impact: 1 Billion Patients With Improved Access In 2030
- 5G Regulation: Ensuring Successful Industrial Transformation

Executive Summary

5G is estimated to add close to \$740 billion to manufacturing GDP in 2030

5G has the potential to grow global manufacturing Gross Domestic Product (GDP) by 4%, or just under \$740 billion, by 2030. This forecast is driven by new use cases and improvements in existing applications that 5G uniquely brings compared to other technologies, and how these improvements will impact productivity. The assumptions and analysis were informed by interviews with manufacturing and telecoms industry representatives and a survey of over 100 manufacturers worldwide to validate the benefits of 5G.



Source: STL Partners

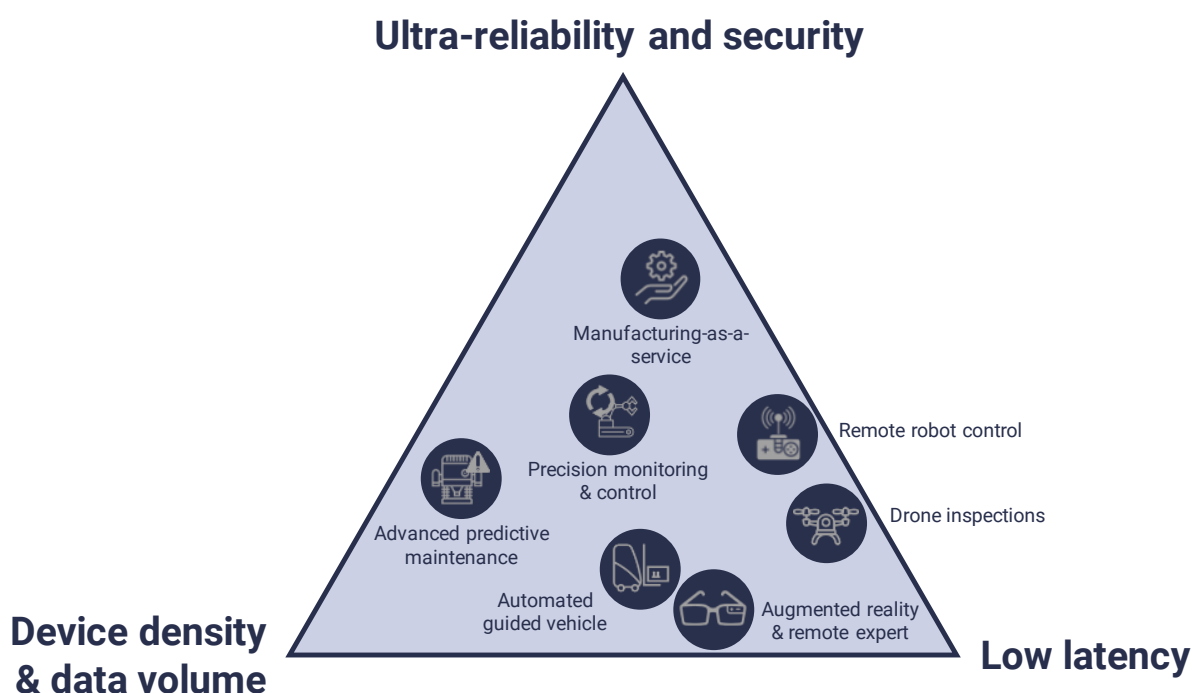
5G's unique capabilities enable new and improved use cases

The manufacturing industry is going through a period of rapid digital transformation and is increasingly using data and technology to improve efficiencies within the plant, enhance productivity, and enable new business models, in an environment where external pressures are mounting. Increased global competition is putting pressure on prices, consumer demands are changing more quickly than ever before, and there are significant skills shortages in the industry.

5G has unique capabilities that allow it to play a significant role in using data – machine, plant, product, and environment data – more effectively. For the manufacturing industry, the three most important advantages stemming from 5G are:

1. The ability to connect many more devices and capture more data;
2. Ensuring connections are ultra-reliable and secure to avoid loss of data;
3. Reduce latency to ultra-low levels of below 10 milliseconds so that data is captured real-time.

As shown below, this opens opportunities across a range of applications, which leverage these benefits to different degrees depending on the nature of the application's requirements.



Source: STL Partners

In the report, we focus on the following three use cases:

- **Advanced predictive maintenance:** collecting huge amounts of data to accurately predict when a machine will fail and reduce unplanned downtime.
- **Precision monitoring and control:** monitoring the entire plant and its processes continuously and adapting processes in real-time to maximise productivity and reduce defect rates.
- **Augmented reality and remote expert:** streaming content for augmented reality headsets to improve efficiency and support workers in maintenance, operational processes, and training.

However, there are challenges to adopting 5G

Although mobile operators are starting to launch 5G in 2019, this does not imply 5G will be ready for manufacturers to use widely. Certain features of 5G that are relevant to manufacturing use cases may not be available for 2-3 years at least and coverage in remote areas will be an issue.

What should the manufacturing industry do?

1. Build an understanding of 5G and its benefits (and limitations) and how it will integrate with other technologies you are using;
2. Input into the development of 5G standards and regulation so the technology is developed so that it meets your needs;
3. Collaborate with telecoms operators now to influence how they commercially deploy 5G in your market and ensure that you are part of the developing ecosystem.

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Introduction: setting the scene

Challenges and future opportunities in the manufacturing industry

The manufacturing industry is going through an era of digital transformation, often termed “Industry 4.0”. This is partly driven by new technology providing the underlying toolkit and a mechanism to improve the business model: cloud, artificial intelligence (AI) and machine learning, new connectivity technologies (5G, Wi-Fi 6, etc.), internet of things (IoT) and sensor technology, digital twins and robotics are all contributing to the digitisation of manufacturing.

Every manufacturer strives to improve efficiencies and grow its productivity levels. Most enterprises look for a 3%¹ improvement in productivity year-on-year, which typically involves more than 100 different activities being reviewed and refined. One important metric used to track performance is Operational Equipment Effectiveness (OEE). OEE measures the effectiveness of a production line and evaluates three factors to give an overall score – availability, performance and quality.

- **Availability:** operating time as a proportion of planned production time. Availability is reduced by unplanned downtime, i.e. time where production is stopped owing to unforeseen issues.
- **Performance:** the extent to which machines are producing output at their optimal rate, i.e. the theoretical maximum speed of production. This is reduced by machines not being in perfect condition.
- **Quality:** the percentage of output that is defective, or that requires rework.

There are three challenges facing manufacturers in all markets that are driving the need to accelerate OEE improvements:

- **Global competition.** Manufacturers must find ways to continuously be more efficient to compete at lower prices or adopt new business models as revenues from the traditional model of selling products are squeezed.
- **Changing consumer demand.** Consumers increasingly expect products to be available “on-demand” and that they be fully customisable, putting pressure on manufacturers to reduce cycle times and create unique products whilst maintaining efficiencies.
- **Labour skills shortages.** The introduction of new technologies creates demand for new skills and the manufacturing industry is struggling to attract new talent, with an estimated 2.4 million positions (or 15% of the total workforce) to be unfilled by 2028 in the US alone².

¹ Based on interviews with manufacturers

² Deloitte, 2018: [2018 skills gap in manufacturing study](#)

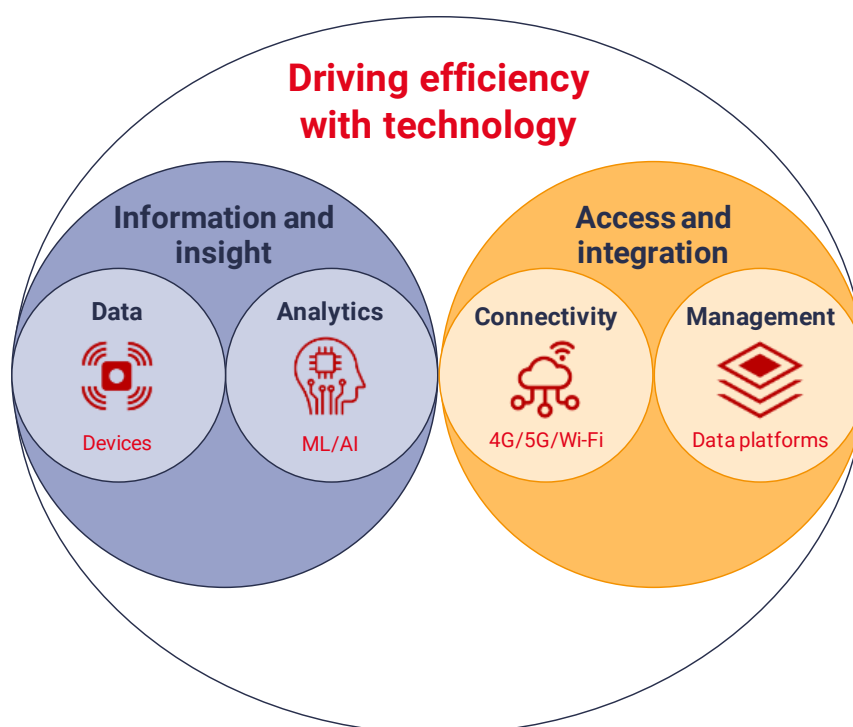
The role of technology in addressing challenges

The key to addressing the above challenges is through improving efficiency – technology will drive this efficiency by enabling rapid digital transformation. Effective use of data is key to making better decisions, however its real benefits will come from creating new business and operating models.

Effective use of data is key

The catalyst to unlocking efficiencies is the generation of richer information and insight, and the ability of users to have simple and real-time access to that information so that better decisions can be made faster. Four key technology pillars underpin these two change drivers (see Figure 1).

Figure 1: The four pillars of technology that will help in driving efficiency



Source: STL Partners

Information and insight

- **Data.** Big data and its potential value in bringing new insights to organisations has been hyped in recent years in many industries. This holds true in manufacturing and industry 4.0 where technological advances allow richer and more granular data to be collected on machines and processes in the plant. One key factor is the ability to collect data using the appropriate sensor. In manufacturing, there has been a proliferation of connected sensors monitoring various conditions: temperature, status (e.g. valve open or closed), pressure, location, humidity, etc.
- **Analytics.** Although monitoring data points (remotely) can itself bring some benefits to the operating plant, analysis of time series data and cross-referencing with other data sources, combined with machine learning or artificial intelligence will significantly improve the way in which data can be used to enhance processes, asset use, supply chain, product design, etc.

Access and integration

As useful as having more information is, if those who need it cannot access the information when they need it, its value cannot be derived. The industry will therefore need:

- **Connectivity.** Underpinning the digital transformation of the manufacturing industry is connectivity – allowing information to be transferred reliably, securely, and in real-time, between processes and equipment within the plant and between different parties – the manufacturer, supply chain partners, maintenance providers, etc. Communication solutions such as 4G, Wi-Fi, and now 5G, help ensure the connectivity required can be delivered easily with the performance needed.
- **Management.** In order to be of value, the many sources of information on machines/processes/systems need to be integrated into existing systems and accessible by the right people at the right time. This would ideally be through a unified platform/portal to remove the need for siloed efforts.

Technology drives new business and operating models

By accessing and using data more effectively, manufacturers can make better decisions. For example, having an accurate view of processes in real-time and enriching this insight with AI can mitigate risks of error in production. Fundamentally, technology will help to change the way in which manufacturers operate:

- **Flexible operations:** consumers' needs are changing more quickly now than ever before; the output a manufacturer produces will rapidly need to adapt to meet new demand. Connected systems that leverage the cloud or cloud-like infrastructure on premises are easier to change, as they are not tied to capital. This means they are flexible enough to create different products at short notice. These characteristics have been tied to IT systems and processes for years, but industry 4.0 moves this into the OT (operational technology) domain, i.e. to manage the machines and physical processes too.
- **Sharing models:** cloud and data technologies combined will enable shared, "as-a-service" models, so that manufacturers can share plant space and physical infrastructure to reduce their capital costs. By decoupling the systems and processes from the physical objects they control, the same assets and infrastructure can be used by multiple users.
- **Service models:** continuous insight on products allows manufacturers to provide services on top of the products they provide, for example using data from in-life products to offer maintenance services after sale or even moving to the Rolls-Royce model of selling "hours of operation" rather than "engines."

Relevance of 5G in manufacturing

While most agree that better use of data can drive better decision-making, there are still obstacles to making this happen. For example, manufacturers are not able to connect their machines, tools and plants easily or aggregate data across siloes in a standardised way.

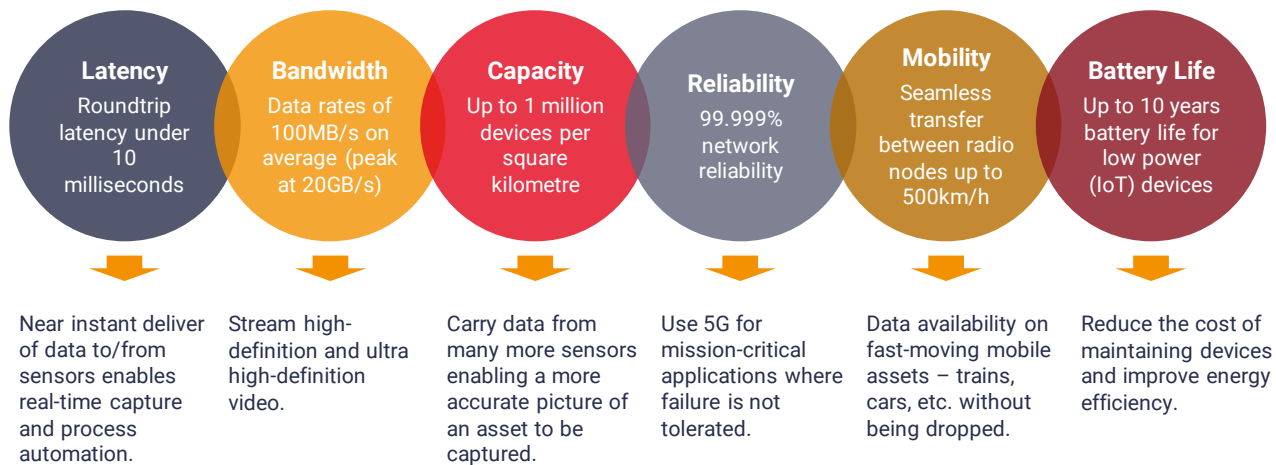
5G has the potential to overcome some of these obstacles, although it is often used as a catch-all term for multiple technologies. So, what is 5G specifically and why is it considered so exciting for manufacturing?

What is 5G?

5G is the latest generation of mobile technology, distinct from previous generations because it is not simply a step up from 4G in terms of speeds. It is software-based by nature therefore more flexible than previous generations of cellular technology. Rather than one network that fits all, customers will be able to use different characteristics of 5G tailored to meet the requirements of specific applications.

5G has been designed to consolidate requirements from multiple different use cases – whether the focus is on ensuring ultra-reliable connections, enabling low latency applications, supporting a massive number of devices, etc. A summary of the technological capabilities is found below.

Figure 2: 5G’s technological capabilities and their implications for users



Source: ITU, STL Partners

Benefits of 5G for the manufacturing industry

Broadly speaking, there are two ways 5G benefits the manufacturing industry: improving industry access to connectivity and enabling new use cases and applications.

Improving industry access to connectivity

Factories have historically used fixed networks (ethernet) to connect, which take a significant amount of time and cost to deploy. It's also meant that manufacturers in markets without developed fixed infrastructure have not been able to advance their manufacturing processes as quickly.

5G provides an alternative to traditional networking, because it has the capacity to carry as much bandwidth as fixed networks at high enough speeds. This is particularly beneficial for those manufacturers in countries with limited fixed infrastructure but relatively mature mobile network infrastructure. They will now be able to use 5G fixed wireless access and access broadband without the need to install cables. This will allow manufacturers who have been slower to progress in digitalisation to leap-frog to Industry 4.0.

New use cases and applications

5G's unique capabilities will unlock applications that have not previously existed, or at least not to the same degree. Interviews with industry representatives highlighted that the most important advantages 5G brings are: device density and data volume (linked to the capacity and bandwidth capabilities), ultra-reliability and security and low latency.

5G increases the **data volumes** manufacturers have available to them on their production facility, by multiplying the number of devices that can be connected and the amount of data that can be carried through the network. This means going from collecting one or two variables on a piece of equipment to monitoring dozens of indicators. A plant operator can thus view the status of machines, processes and systems to a more granular degree and identify problems accurately.

5G is more **reliable and secure**, particularly compared to Wi-Fi. For manufacturers to be comfortable with using data to automatically control their processes and systems, they need to make sure that data is accurate and collected reliably, plus that it cannot be accessed by third parties.

Finally, **low latency** is a key factor in using 5G to enable new use cases, where data is not only used to monitor assets, but trigger real-time actions. Mission critical applications that are core to industrial processes have extremely low latency requirements of ten milliseconds or less.

Figure 3: Key benefits of 5G according to the manufacturing industry



| Device density & data volume | Ultra-reliability and security | Low latency |
|---|--|--|
| <p>☞ Enables ramping the amount of sensor data currently collected – CEO, Manufacturing Company</p> <p>☞ Using IoT data for fault detection requires 5 million data points observed in plant with gigabytes of data being generated per second – COO, Industrial IoT company</p> <p>☞ We expect 5G to drastically ramp up out current data analysis activities – CEO, Manufacturing company</p> | <p>☞ Alternatives [to 5G] can be insecure or unreliable. Wi-Fi suffers from ‘white spots’. Bluetooth is complicated and both have high costs of maintenance – CEO, Manufacturing</p> <p>☞ Most manufacturers will want to use a secure, private 5G network solution – COO, Industrial IoT company</p> <p>☞ Wi-Fi seen as having significant security concerns – Partner, UK 5G testbed</p> | <p>☞ Machine tool monitoring requires latency below 10ms – Head of Department, Application research organisation</p> |

Source: STL Partners

New and improved use cases and applications enabled by 5G

The use cases and applications that will be enabled by 5G leverage the three most important capabilities: device density, latency and ultra-reliability and security.








On the next page is a set of use cases that will take advantage of these benefits and make a tangible difference to a manufacturer's business model. For example, although manufacturers have used automated guided vehicles (AGVs) for years for materials handling and logistics within the plant, they often use rigid routing using floor markers to guide movement. 5G will enable AGVs to operate in unstructured environments and adapt routes according to their surroundings using data from multiple sensors interacting with intelligent systems.

We deep dive on three use cases later in this section that have been used as the basis to determine the level of impact 5G-enabled use cases will have on manufacturing GDP:

1. Advanced predictive maintenance
2. Precision monitoring and control
3. Augmented reality and remote expert

These have been chosen as they have specific requirements that use 5G and are sufficiently relevant to enterprises to make a tangible difference on productivity and efficiency.

Figure 4: Use cases in the manufacturing industry enabled by 5G

| Use case | | | Benefits | Why 5G? |
|---|--|--|--|--|
|  | Advanced predictive maintenance | Using dozens of sensors to give an accurate, real-time representation of the status of a machine to perform predictive and preventative maintenance | <ul style="list-style-type: none"> Reduce downtime Reduce spend on maintenance Reduce machine replacement rate | <ul style="list-style-type: none"> Device density Reliability Device costs |
|  | Precision monitoring & control | Real-time monitoring and control of robots / machine tools / end-product (e.g. change speed of process based on vibrations) | <ul style="list-style-type: none"> Reduce defects Increase throughput Increase yield | <ul style="list-style-type: none"> Device density Ultra-low latency |
|  | Augmented reality & remote expert | Using augmented reality headsets to guide worker via augmented display and/or remote expert when carrying out maintenance and repair tasks | <ul style="list-style-type: none"> Reduce spend (and time) on maintenance and repair Reduce spending on training | <ul style="list-style-type: none"> Bandwidth (video data) Ultra-low latency |
|  | Remote robot control | Controlling robotic machinery remotely (video link may be required) for tasks where human involvement may be hazardous | <ul style="list-style-type: none"> Health and safety Increase throughput | <ul style="list-style-type: none"> Ultra-low latency |
|  | Manufacturing-as-a-service | Making manufacturing flexible and mobile by reducing time to set up a site (fixed infrastructure) and enabling multiple parties to use same facility | <ul style="list-style-type: none"> Increase rate of product innovation Reduce overall costs Increase productivity | <ul style="list-style-type: none"> Flexibility Ubiquity Device costs |
|  | Automated guided vehicle | Coordinating vehicle control of AGVs (e.g. forklifts, pallet movers or tractors) in a more flexible way - without needing to pre-define routes | <ul style="list-style-type: none"> Increase efficiency Increase productivity | <ul style="list-style-type: none"> Low latency Reliability Location-awareness |
|  | Drone inspections | Using drones to perform tasks that may be difficult, dangerous or tedious for humans (e.g. inspecting hard to reach equipment, checking inventory) | <ul style="list-style-type: none"> Health and safety Reducing spend (and time) on inspections | <ul style="list-style-type: none"> Low latency Reliability Location-awareness |

Source: STL Partners

Advanced predictive maintenance

Unplanned downtime is one of the biggest problems for manufacturers and can cost up to nine times more than planned downtime. This is particularly important for high speed assembly lines where the cost of a machine failing can be more than \$10,000 per minute, according to one of our interviewees. On average, 4.7%³ of planned production time is lost due to unplanned downtime from machine breakdown.

When equipment breaks down without warning, the implications are profound, and a repair process is initiated:

1. Production stops;
2. Maintenance staff (on-site or third party) assess the problem;
3. Parts are ordered;
4. A specialist may need to be scheduled to conduct the repair on site.

In order to avoid these costs, manufacturers have historically used scheduled maintenance visits to ensure equipment is in good condition, but this results in downtime (planned stoppages for maintenance) and can result in unnecessary spending (incurring maintenance and repair costs when the machine does not require it.)

Predictive maintenance has been around for several years and seeks to address these issues – approximately 17% of survey respondents claimed that they have implemented it widely across the organisation. By equipping machines with sensors, conditions can be monitored in real-time and a combination of parameters evaluated to determine when a machine will break down ahead of time. This means that not only is breakdown avoided but spend on traditional servicing is reduced and the lifetime of an asset extended.

The theory of predictive maintenance is easy to understand but the benefits have not materialised in the way they were envisioned. Partly this is because there have been challenges integrating the insights from operational technology into IT systems (e.g. ERP systems). Other issues stem from the inability to predict outcomes effectively because there are not enough variables being measured and the machine learning platforms are not mature enough to produce real insights.

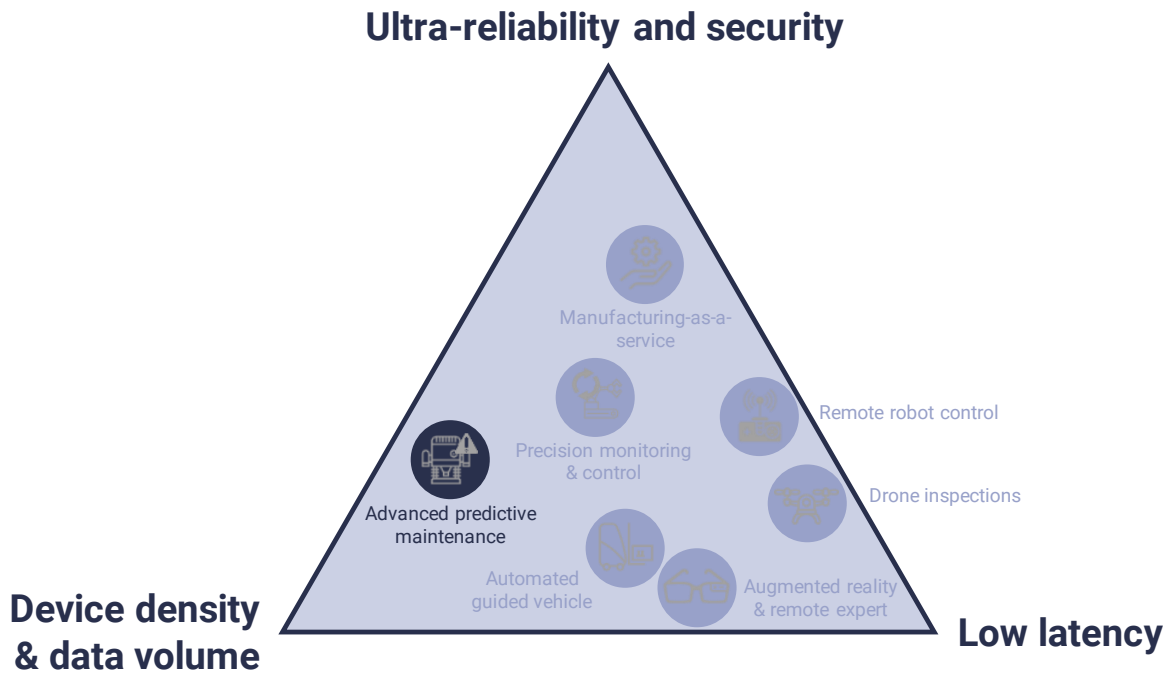
Why 5G?

5G will support a new wave in predictive maintenance – what we have termed “advanced predictive maintenance.” This means increasing the number of sensors fitted to equipment from one or two to measuring dozens of different parameters – temperature, vibrations, humidity, pressure, etc. – and ensuring the data is always collected reliably in real-time. This is important because the value comes from analysing the data, cross-referencing it with historical data and trends to proactively predict

³ Based on results from STL Partners survey with manufacturers, August 2019

outcomes. Data needs to be as complete as possible to make sure that anomalies are not missed, as it could be a single data point that detects the issue and determines whether the machine needs to be repaired.

Figure 5: Advanced predictive maintenance mapped to 5G benefits



Source: STL Partners

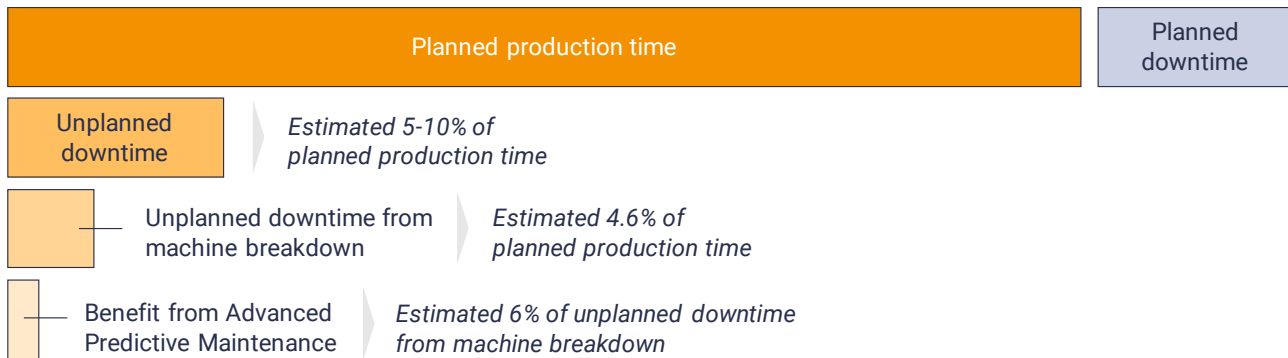
Impact on the manufacturing industry

There are many stakeholders who benefit from implementing advanced predictive maintenance:

1. **Manufacturing plant owner.** The ways in which advanced predictive maintenance would benefit the manufacturer span from reducing spend on servicing machines to increasing the lifetime of the asset. These are explored in detail in Figure 7. However, the most important benefit to the plant owner is the reduction in machine downtime, as this means the plant is operating closer to planned production time. It is estimated that implementing advanced predictive maintenance can reduce machine downtime by 6%⁴, which is a huge impact even if machine downtime constitutes a small portion of planned production, as seen below.

⁴ Based on results from STL Partners survey with manufacturers, August 2019

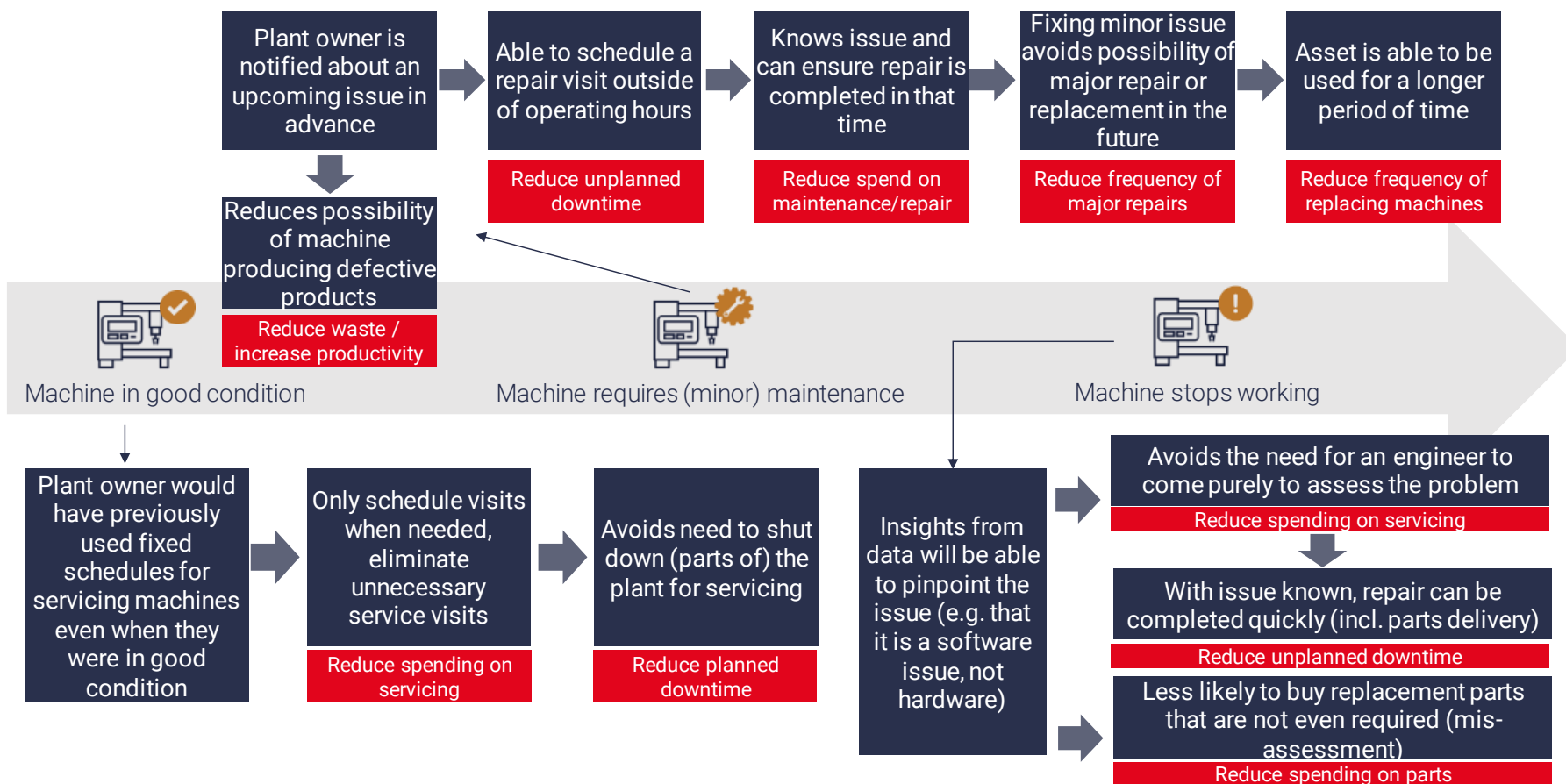
Figure 6: Impact of advanced predictive maintenance on unplanned downtime relative to planned production time



Source: STL Partners, estimates based on results from STL Partners survey with manufacturers, August 2019

2. **Maintenance services provider.** Original equipment manufacturers often provide maintenance services for their machines that reside in the plant. Advanced predictive maintenance firstly allows them to use the data to offer additional services to their customers, e.g. proactive servicing of equipment. It can also help to improve productivity levels by reducing the number of visits maintenance staff make to customer sites. Engineers would not need to go to the customer's plant to service machines on a fixed schedule, solely in the event of a breakdown, and once at the plant, they would be able to conduct the repair much quicker, having known the root cause from the results of the analysis by the predictive maintenance platform. This allows the field force to spend time on more significant problems where their skills are required.
3. **Equipment manufacturers.** Create new revenue streams through new services, either providing dashboards on machine conditions or by completely altering the business model and selling equipment by time rather than as a one-off purchase
4. **Machine parts suppliers.** Leverage the insight to improve their products and, by knowing when break downs occur in advance, they ensure parts are sent on time and reduce delays for their customers

Figure 7: Benefits of advanced predictive maintenance in the manufacturing plant



Source: STL Partners

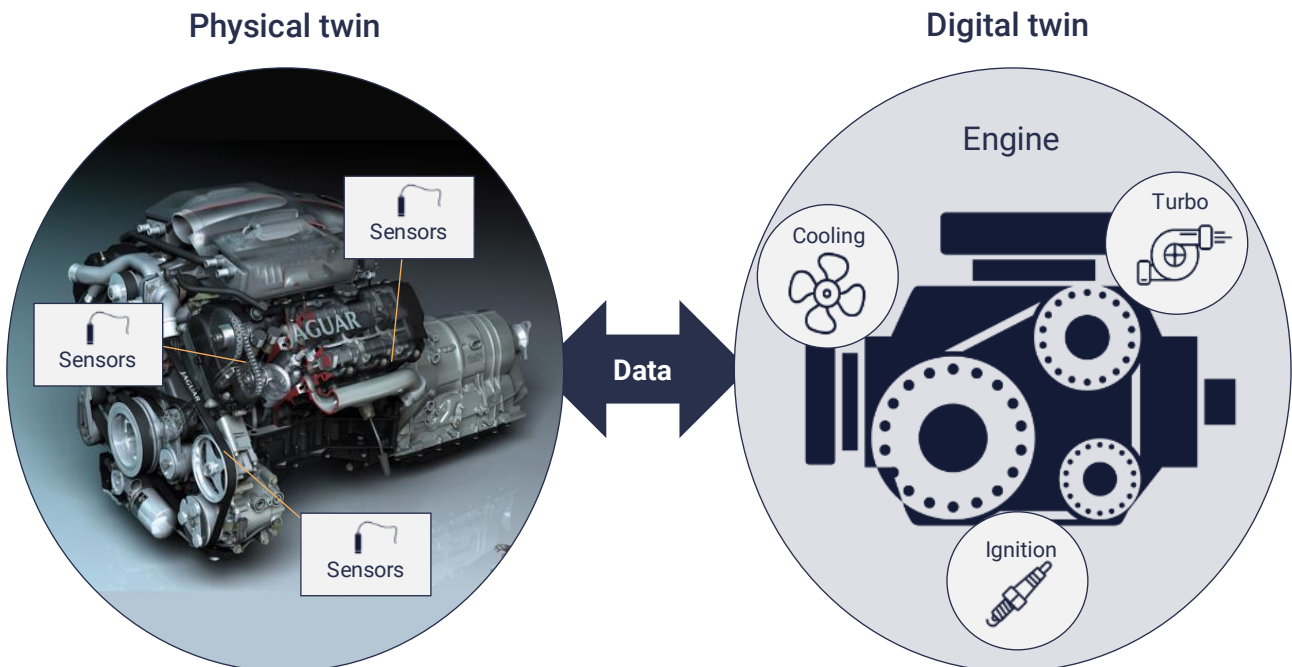
Precision monitoring and control

Reducing downtime is an important factor in maintaining the smooth running of the production facility, however manufacturers also need to ensure they are getting the most out of their machines when they are running. When a machine is not working at its theoretical maximum rate then the time it takes to produce a given output (cycle time) is lower than it should be. On average, manufacturers estimate machines are producing 83%⁵ of their maximum potential.

Equipment may also malfunction to produce defective products, therefore reducing yield and increasing the amount of time needed to rework products or produce them from scratch. Our survey found that approximately 4%⁶ of output is defective. This is an even bigger problem when processes are not monitored during the production cycle and any issues in production cannot be identified until much later.

Precision monitoring and control can resolve some of these issues by analysing data to make changes to the production process in real-time. This is done through multiple sensors monitoring the entire process: machine parts, manufacturing equipment and the product itself to obtain an accurate view of its status in real-time. The sensor data could be used to create digital twins, i.e. digital representations of an existing physical entity. An example of this from a previous STL Partners report '*Digital twins: A catalyst of disruption in the Coordination Age*' is shown below.

Figure 8: Using sensors to create digital twins in manufacturing



Source: STL Partners

⁵ Based on results from STL Partners survey with manufacturers, August 2019

⁶ Ibid.

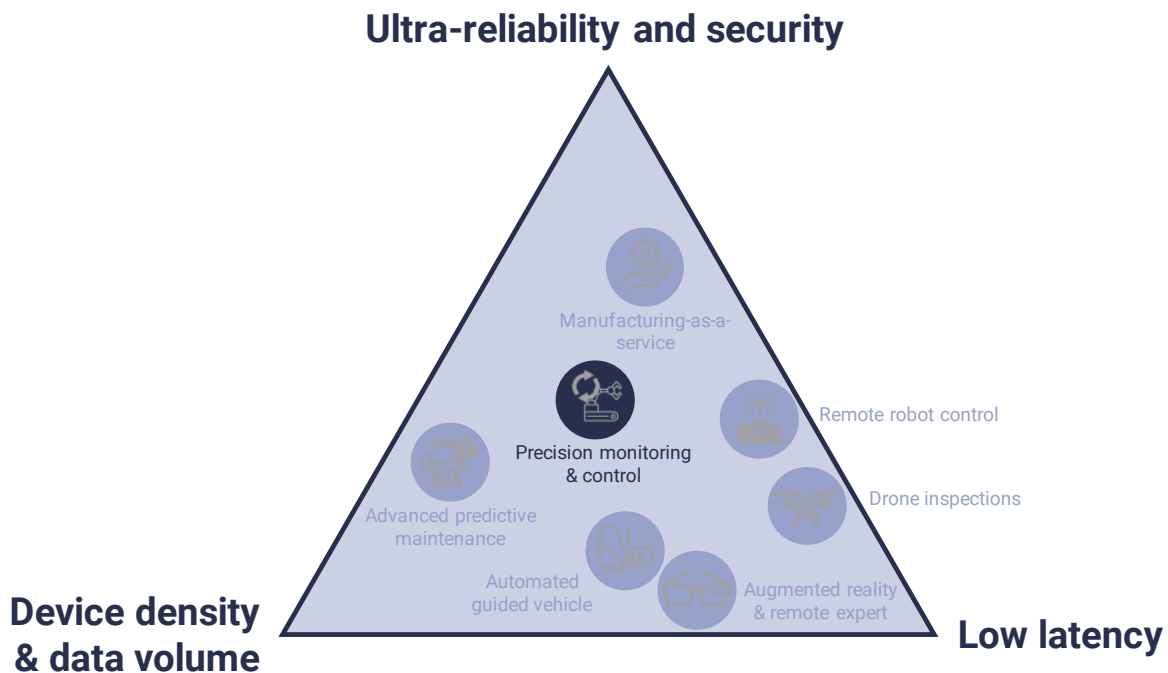
These digital twins and the analysis of the sensor data would first determine whether there were any discrepancies with the planned model or process and then be incorporated into predictive models to determine how the process and/or the behaviour of the machine tool should be adapted. In an autonomous environment, smart machines would implement the recommended action and self-correct without the need for human intervention.

Early adopters are starting to use forms of this technology, for example Marvin⁷, a US manufacturer of windows and doors, uses lasers to monitor the pieces of wood as they are being made and visualise the knot and grain structure to identify defects. However, this use case is not only relevant at the machine-level; in continuous production lines, a defect by one machine may need to be corrected by another down the line, which requires a significant level of analytics to coordinate across the plant. Machine learning and AI play a critical role here to learn from the analysis over time and recognise new defects that are not in the data set used to train the algorithm.

Why 5G?

5G is an important enabler of this use case given that ultra-low latency is required, for example adapting the actions of a machine tool in real-time cannot tolerate latency above 10 milliseconds. In order to create an accurate digital twin of the process and product, data from sensors always needs to be collected continuously and reliably. This avoids the possibility of missing the relevant data point that identifies the anomaly or feeding incomplete data into the analytics system that would risk misdiagnosing the situation. Alternatives, such as Wi-Fi or LTE, do not provide that same level of reliability and quality of service.

⁷ CFO Magazine, 2017

Figure 9: Precision monitoring and control mapped to 5G benefits

Source: STL Partners

Impact on the manufacturing industry

Precision monitoring and control transforms the way in which the manufacturing plant runs and how plant owners seek to optimise processes. There are four ways this use case brings tangible benefits to the manufacturer:

1. **Reducing defective products:** identifying any product flaws as they emerge and fixing these immediately and/or adapting the machine tool/process to avoid any further defects being produced. This is estimated to reduce average defect rates by 10%⁸ on average.
2. **Improving machine performance:** recognising when a machine is not working optimally (e.g. milling tool slowing down) and adjusting it to maintain cycle speeds. Manufacturers believe this has the potential to improve machine productivity by 15%⁹ on average.
3. **Reducing spend on (traditional) quality control:** as quality of the end-product is monitored throughout the production process, manufacturers move away from traditional quality monitoring that require a separate dedicated team, process and additional costs.
4. **Increasing asset lifetime:** manufacturers replace machines if the machine is deemed to be underperforming and not producing a minimum level of yield, but by continuously increasing the

⁸ Based on results from STL Partners survey with manufacturers, August 2019

⁹ Ibid.

performance of a machine through small adjustments, machines will not have to be replaced as frequently.

Augmented reality and remote expert

The manufacturing industry is suffering from a skills shortage problem and it is estimated to face a deficit of 7.9 million workers globally¹⁰ by 2030.

This is partly because manufacturers are finding it difficult to attract talent; the internet giants and tech start-ups are a big draw for engineering graduates. At the same time, rapid adoption of new technology means that new, highly skilled roles are being created and are not easy to fill. Furthermore, these technologies are being implemented on the shop floor, which means manufacturers need to continuously train staff on new processes or equipment.

Augmented reality (AR) headsets are being used in different ways to try and tackle the skills problem, as well as increase productivity across different parts of the plant. At a high-level, this works by providing the user of the headset with a view of what is in front of them plus a relevant overlay, such as key information/statistics or a virtual image. A remote expert can also provide guidance in real-time through live annotations or audio instructions via telepresence.

There are different scenarios in manufacturing where this may be beneficial:

- **Training:** Employees spend on average 7%¹¹ of their time carrying out training. Rather than using resources to teach employees on how to use equipment or on new processes, they can be guided on the job using the AR headset.
- **Health and safety:** reduce risk of hazardous situations, for example by warning workers if they are entering an area that is off limits or by providing hands-on guidance when using specialist equipment.
- **Maintenance and repair:** shop floor staff can be alerted on whether a machine requires servicing and carry out the task without necessarily needing to wait for a specialist or use traditional manuals.
- **Product checks / quality assurance:** the image of the product can be cross-referenced with a digital twin to identify discrepancies and notify the worker as they conduct the check.
- **Complex assembly:** instructions can be directly projected on the display so the worker assembling various components avoids having to pause the job to refer to a separate document for guidance.

¹⁰ Korn Ferry research, 2018

¹¹ Based on results from STL Partners survey with manufacturers, August 2019

- **Plant operations:** as plant supervisors inspect operations throughout the facility, they can be given real-time instructions on issues related to a machine or area, for example receive an alert to change the parameters of a machine tool to optimise production.

Figure 10: thyssenkrupp technicians using AR for technicians servicing elevators



Source: thyssenkrupp

Why 5G?

Today, there are still technical challenges inhibiting augmented reality headsets from being adopted at scale. Most AR applications run on the device itself, which means headsets are of considerable size to process the amount of compute required. In addition, pre-loading content limits the use of the headset, which is particularly problematic in manufacturing given the number of scenarios a single device could be used for: training, maintenance, assembly, etc.

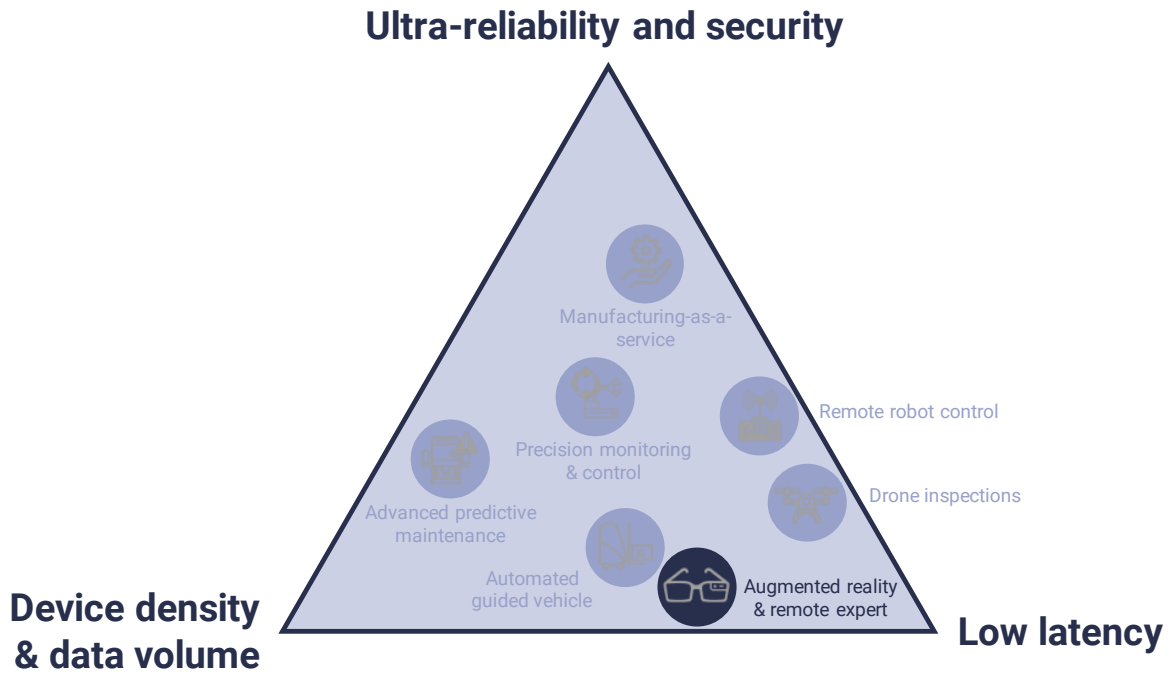
In order to offload the compute to the cloud, the connection between the device and the cloud needs to support high bandwidth levels for the high definition video streams and ultra-low latency to avoid dizziness for the end-user. This lends itself to 5G, since average latency in LTE and Wi-Fi are too high at an average of 80ms and 150ms respectively¹².

5G is particularly useful for situations where there is a degree of mobility, such as for a maintenance service provider. When servicing a machine at a customer's plant, it is impractical for the maintenance

¹² [Future Networking Challenges: The Case of Mobile Augmented Reality](#)

provider to have to access the customer’s Wi-Fi network to use the AR application and conduct the task, therefore cellular technology would be a more viable option.

Figure 11: Augmented reality and remote expert mapped to 5G benefits



Source: STL Partners

Impact on the manufacturing industry

Yamazaki Mazak, a Japanese machine tool builder, estimates a 2% improvement in productivity for their service engineers from using AR, based on initial tests from the UK 5G testbed. However, the benefits are not only to the maintenance provider, but to the manufacturing plant itself by reducing machine downtime. In the event of a machine breaking down, up to 28%¹³ of the time is spent waiting for specialists to arrive for the repair and 21%¹⁴ is on conducting the repair itself. Manufacturers estimate that AR-assisted maintenance can reduce the time taken to repair a machine by 25%¹⁵ since the worker carrying out the maintenance task has access to better information.

¹³ Based on results from STL Partners survey with manufacturers, August 2019

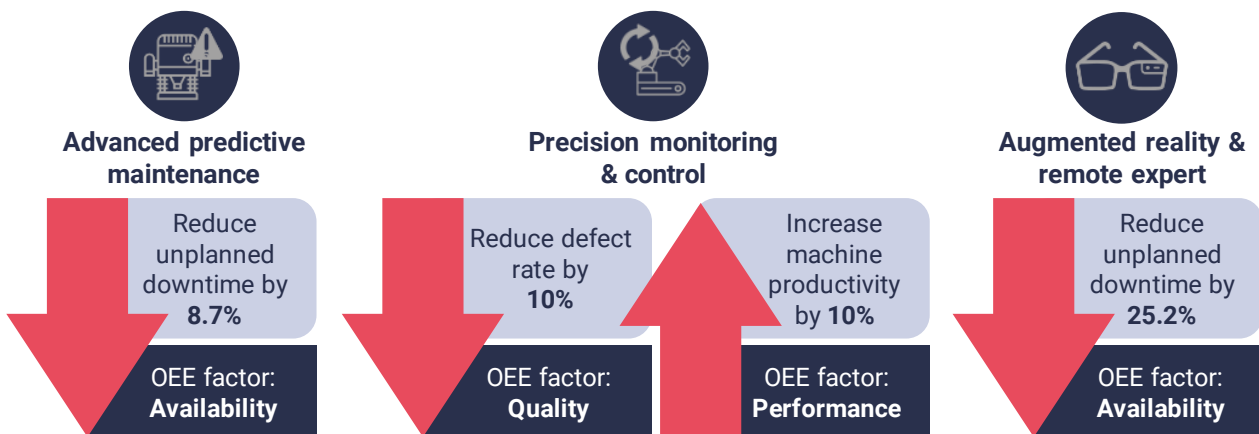
¹⁴ Ibid.

¹⁵ Ibid.

5G impact: \$739Bn increase in global manufacturing GDP by 2030

The benefits of 5G to the manufacturing industry have been quantified based on the assumptions on the impact for each of the three use cases discussed earlier. As referred to in the introduction, manufacturers seek to improve operational equipment effectiveness (OEE) to improve productivity. Each of the use cases above affects OEE in different ways, whether it be by increasing uptime (availability), improving machine productivity (performance) or increasing yield by reducing defects (quality).

Figure 12: Impact of 5G use cases on OEE

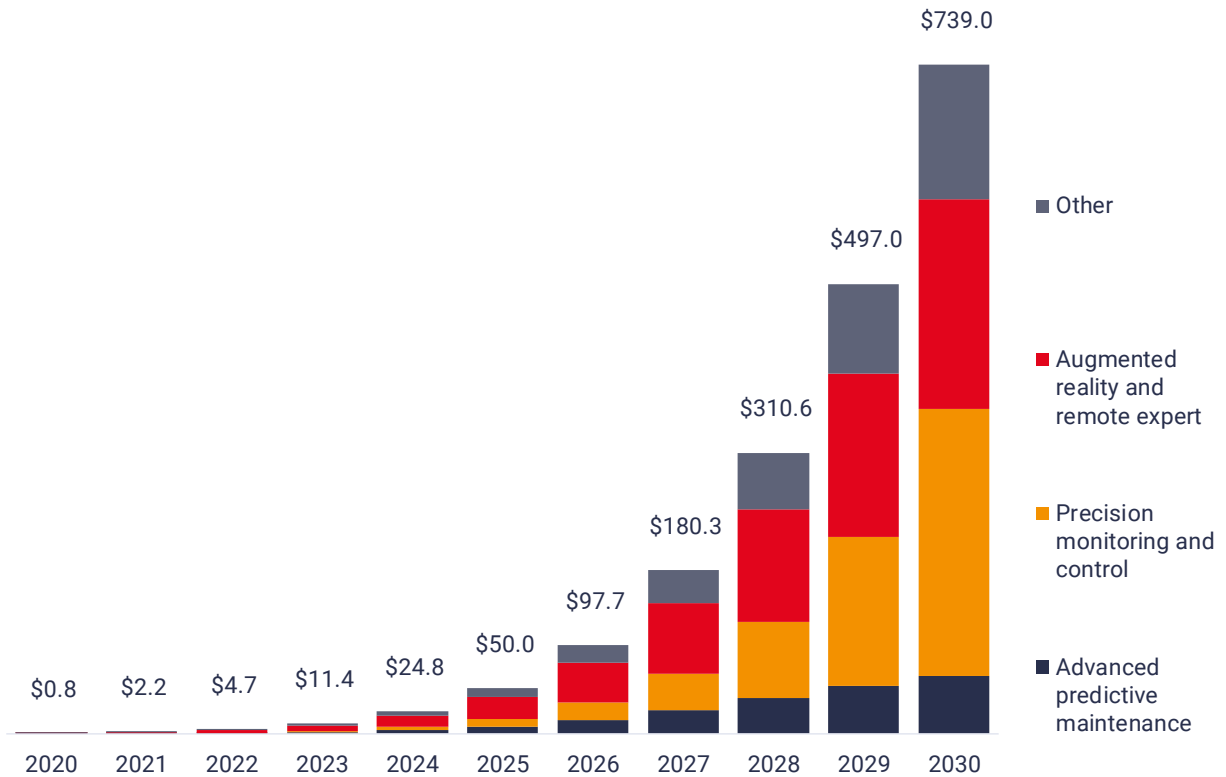


Source: STL Partners' analysis based on results from survey with manufacturers, August 2019

By looking at the impact of these use cases on aggregate and forecasting adoption over a 10-year period, 2020-2030, we estimate that in 2030 world manufacturing GDP (Gross Domestic Product) would increase by \$591 billion. Assuming other use cases would also have an impact, making up a further 20% of the total potential impact, the overall impact on manufacturing GDP increases to \$739 billion. representing a 4% uplift on expected GDP in 2030.

Precision monitoring and control has the highest impact on manufacturing GDP by 2030 at \$295 billion, unsurprising given its revolutionary nature in changing the way in which production facilities optimise performance of machines and processes. However, adoption of the use case is slower than that of the other use cases. Firstly, this is because it requires sophisticated technologies, such as digital twins and machine learning to enable predictive models, and a high degree of integration into a manufacturer's core processes. The other factor that will impact adoptions is the fact that this use case requires ultra-reliable low latency 5G for real-time identification of problems and this capability will not be available until later stages of 5G.

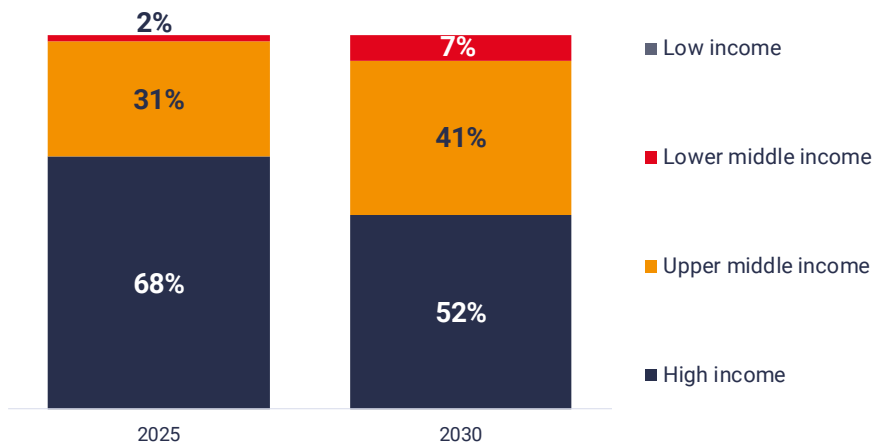
Figure 13: Estimated impact of 5G on global manufacturing GDP (USD Billions) by use case



Source: STL Partners

As seen below, the benefits are initially skewed towards higher income countries, given that these will generally deploy 5G faster and be earlier to adopt new technologies. However, as the applications mature in the early adopting countries, other markets will adopt at faster rates once 5G is in place.

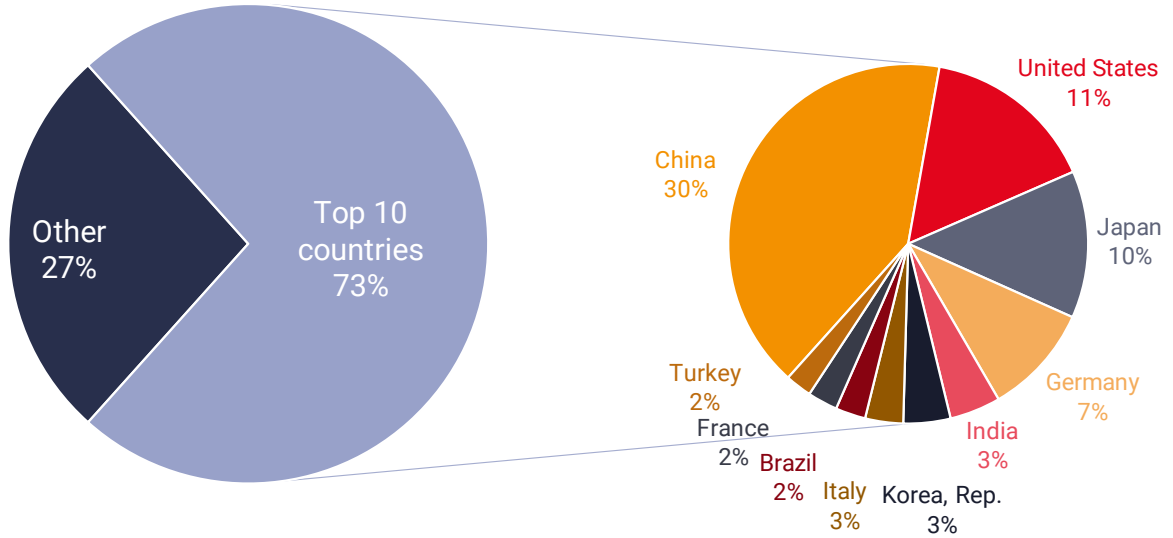
Figure 14: Proportion of global manufacturing 5G benefit by country income level



Source: STL Partners, country income levels as defined by World Bank

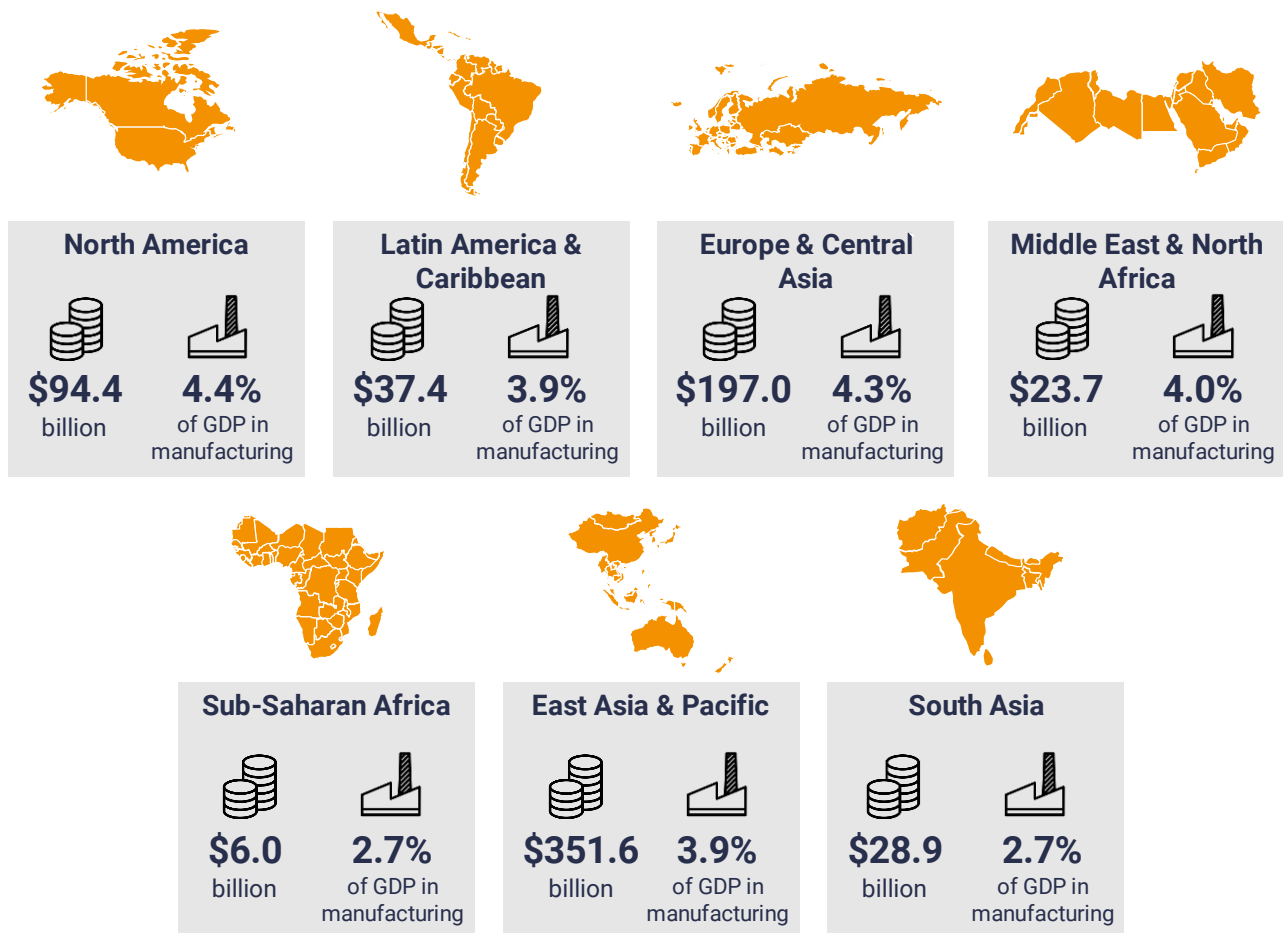
Nonetheless, it is countries that have a strong manufacturing industry that will benefit most. Just under 75% of the impact in 2030 is from the ten largest benefiterers. China and the U.S. constitute approximately 41% of the benefit alone and are both countries that are set to be early adopters of 5G.

Figure 15: Proportion of global manufacturing 5G benefit – top 10 countries



Source: STL Partners

Figure 16: 5G impact on manufacturing GDP by region



Source: STL Partners

This is further emphasised in the regional breakdown. East Asia & Pacific have the highest share of the 5G benefits in 2030 at \$352 billion, as well as other regions with strong manufacturing markets, such as North America and Europe & Central Asia. In some areas, such as Sub-Saharan Africa and South Asia, the impact on manufacturing GDP as a percentage is relatively lower because penetration of these use cases would not have reached maximum by 2030 in certain countries within these markets.

It's not just about money: 5G's socio-economic benefits

The ability for the manufacturing industry to leverage 5G to enhance connectivity and enable new use cases has a socio-economic impact, in addition to improving productivity, efficiency and industrial growth. One of the overarching benefits of 5G is increasing access to information – in real-time, more reliably and from many more devices. These insights can be used to automate decisions that benefit society more broadly.

1. Speed up digital transformation

As with each generation of mobile technology, 5G will push the price of a gigabyte of data even lower than it is today and improve access to internet connectivity, particularly in developing countries. In areas where fixed line infrastructure is lacking, 5G offers a viable alternative and provides the same level of bandwidth that comes with fixed access. Factories who have not been able to digitalise as quickly because of suboptimal network infrastructure can now leapfrog with 5G and use connected technology to enhance their operations.

2. Improve use of resources

Some of the use cases we analysed previously in the report will enable more responsible consumption of resources. We have already examined the impact of advanced predictive maintenance on extending the lifetime of capital assets. In sectors which use perishable materials, predictive maintenance reduces waste that occurs from unplanned downtime incidents where raw goods are discarded if not used in good time. Separately, implementing precision monitoring and control reduces the number of defects by adapting processes in real-time that may have otherwise caused machines to produce faulty output that would have been wasted.

3. Share production facilities

5G will be a key enabler for creating a sharing production economy in the manufacturing sector. In a similar way to what we have seen in consumer markets through Uber and Airbnb and business through WeWork, manufacturers will benefit from being able to share resources more easily and implement new business models that are capital-light, such as manufacturing-as-a-service. As processes and intelligence move to the cloud, manufacturers are less tied to their physical assets and more mobile. It makes it much easier to produce highly customised products or pivot to new products without needing to use additional capital resources. Taking this a step further, companies like Startup Factory in China are creating shared factory spaces, where European manufacturers can set up shop in China and share space and equipment. However, this relies on IoT and all machines to be connected centrally, which is where 5G plays a part.

4. Optimise energy usage

The use of IoT and sensors to monitor the manufacturing plant will also allow plant operators to optimise the use of energy and reduce the amount used where possible. 5G assures more granular analysis of shop floor processes by proliferating the number of sensors that can be used in a single location. The huge increase in the amount of data, coupled with machine learning and advanced analysis, means that the amount of energy demanded by the plant can be predicted in advance, making it easier to use renewable energy sources. Other sources of impact on energy usage include adopting remote working more effectively, for example a technician on-site can carry out tasks with the expert looped in remotely via AR headsets to avoid skilled technicians travelling long distances.

5. Close the skills gap

5G use cases can help grow economic productivity by complementing human processes with technology. Augmented reality headsets linked to remote experts will quickly upskill workers and enable them to use technology and machine tools more effectively. This reduces barriers to

employment in the manufacturing industry and is hugely beneficial given the increasing skill gap. Plus, it allows manufacturers to more easily move to new markets and employ the local workforce there.

6. Improve health and safety

Working conditions can be made safer by removing humans from dangerous areas through automation and remote operations via 5G networks. Mitigating risks related to health and safety is a challenge in the manufacturing industry relative to other sectors. The chart below shows that it constituted the largest proportion of non-fatal work injuries in the EU in 2016 (20%) and about 16% of fatal injuries across all industry sectors. An example of using technology to reduce the number of work-related injuries and health problems includes drones to inspect equipment that is too high to reach safely or contains hazardous materials. Similarly, by monitoring conditions in the plant continuously, any warnings can be flagged to a worker wearing AR headsets in real-time on the display, such as in an incident where a machine a technician is working on is starting to malfunction.

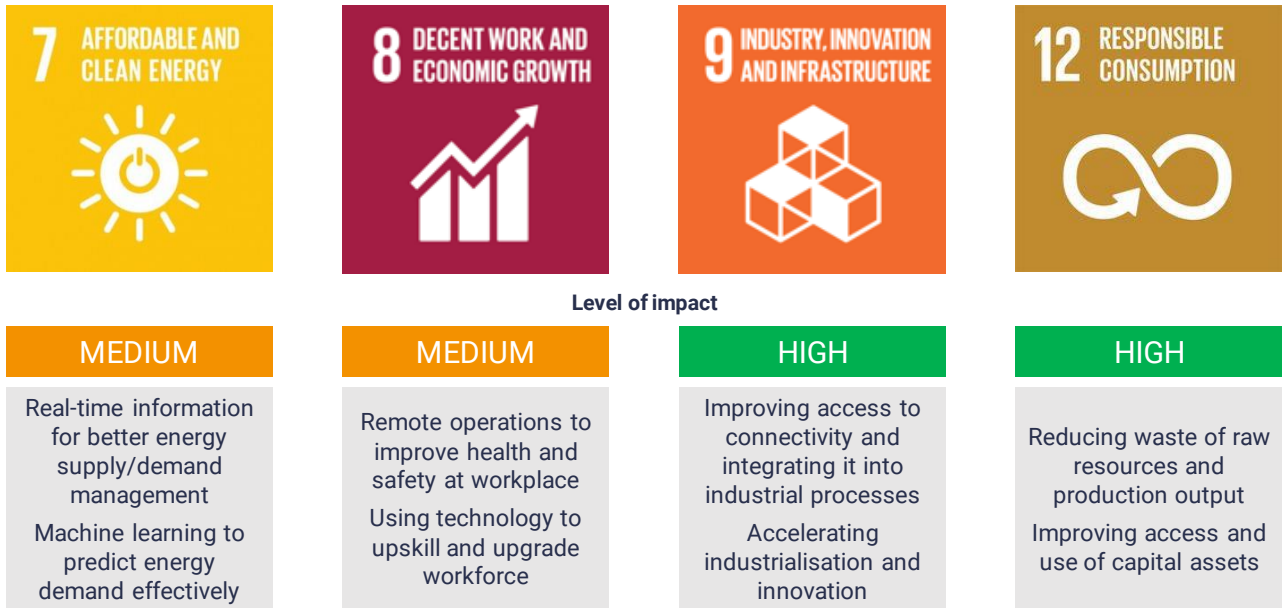
Figure 17: Fatal and non-fatal work injuries by industry (EU, 2016)



Source: Eurostat

These benefits can be summarised in four of the United Nations’ sustainable development goals (SDGs). Most of the impact from 5G in manufacturing manifests itself in improving infrastructure and accelerating industrialisation (SDG 9) and ensuring consumption and production are more sustainable (SDG 12.)

Figure 18: How 5G in manufacturing benefits UN SDGs



Source: United Nations, STL Partners

Next steps for the manufacturing industry

Challenges with accessing 5G

Although there is huge potential benefit for 5G to impact the manufacturing industry, there are still challenges that may hinder the ability for manufacturers to leverage its capabilities. Some of this is due to aspects outside of 5G per se, for example the fact that many of the applications described require data to be accessed from siloed systems and processes, need advanced technologies such as machine learning and must be integrated back into a manufacturer’s existing processes to improve operations automatically.

Outside of these, there are potential challenges related to purely accessing 5G. Although mobile operators have already launched 5G in the advanced markets or having announced the availability of 5G in the next 1-2 years, this does not imply 5G will be ready for manufacturers to use widely. This is because the initial characteristics of 5G are will not necessarily benefit manufacturers immediately, as they focus on increasing bandwidth and speeds for consumer applications. In addition, coverage in remote areas will be an issue.

5G will evolve and the standards are still being set

Although targets have been defined, the telecommunications standards body 3GPP is still in the process of defining the standards for the next release of 5G. This is important because it means that the 5G that has been launched so far by operators does not include the enhancements that will enable ultra-reliable low latency applications such as precision monitoring and control.

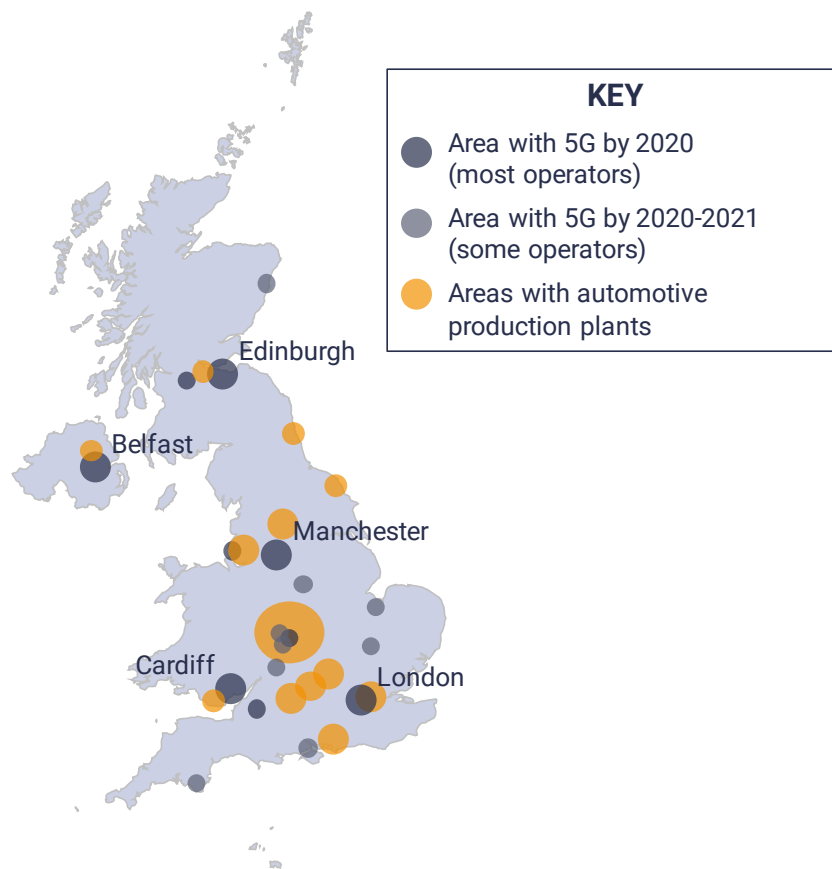
Figure 19: Scope of 3GPP standards releases

| Release 15 | Release 16 |
|--|--|
| 2018 | 2019-2020 |
| <ul style="list-style-type: none"> Enhanced mobile broadband (e.g. mobile video streaming): speed, bandwidth, capacity Fixed wireless access (using cellular technology for fixed broadband) | <ul style="list-style-type: none"> Massive machine type communications (i.e. IoT): number of connections, low cost devices, low power, increased battery life Industrial IoT Ultra-reliable low latency (e.g. mission critical applications, augmented reality): reliability, latency V2X (i.e. vehicle-to-anything: communications): connected/autonomous car use cases such as platooning, automated driving |

Coverage in remote areas is not guaranteed

Telecoms operators traditionally follow consumer populations when rolling out networks. For 5G, they are set to target major cities, however many manufacturing facilities are in remote areas that fall outside these domains, which poses a challenge for how quickly manufacturers will access 5G. The mismatch between areas where production plants are located and the initial targets for 5G launch are shown in the chart below, which marks UK operator's planned targets and the locations of automotive manufacturing facilities, as a representative sample.

Figure 20: Comparison of UK 5G roll-out target cities and the locations of automotive production facilities



Source: 5G.co.uk, European Automobile Manufacturers Association

The manufacturing industry's role in accelerating 5G adoption

Despite these challenges, there is an opportunity for the manufacturing industry to change the trajectory by working with telecoms industry more closely. 5G is unique to its predecessors because of the way in which it seeks to be a technology that is relevant to industry and engage sector representatives to do so. In order to ensure the benefits of 5G come to fruition, there are three activities manufacturers should engage with:

1. Build an understanding of 5G and its benefits

2. Input into the development of 5G standards and regulation
3. Collaborate with telecoms operators

Build an understanding of 5G and its benefits

The challenge of 5G will be in bringing different parties from different industry sectors together to work on the effective use of 5G to drive industrial growth. Manufacturers, in general, are not aware of the technical specifications of 5G, how it compares to other technologies, and how it will evolve over time. One of 5G's benefits is that it is flexible and will meet different requirements based on different industries and customers, however this requires a certain skillset to marry the needs of the manufacturers with the right network technology choice. Historically, this has either been the role of the communications service provider or a systems integrator, although the challenge of relying on systems integrators is that they may not be adequately informed on the breadth of options available. Therefore, it is important for the manufacturer to have some awareness, as well as working with solution partners and network experts.

Cross-industry initiatives are helping to bridge the gap between the telecoms and the manufacturing industries, not least to create a common language when discussing the technological benefits, use cases and industrial requirements. Some notable country-specific cross-industry associations that are striving to do this include:

- European Factories Of The Future Research Association (EFFRA) – Europe
- Made Smarter – UK
- Alliance of Industrial Internet (AII) – China
- Made in India
- Alliance for the Industry of the Future - France

Input into the development of 5G standards and regulation

As well as building an understanding on 5G to make better business decisions between network options, manufacturers should also seek to do so to influence the telecoms industry and its stakeholders in developing standards and regulation for 5G.

5G standards will continue to evolve ahead of each release as the telecoms sector tries to ensure that 5G can meet the needs of industry. 3GPP has invited "Market Representation Partners" to take part in influencing standards, who include the 5G Alliance for Connected Industries and Automation (5G-ACIA) and the 5G Automotive Association (5G AA.) There are specific study items in 3GPP on "Communication for Automation in Vertical Domains" and "LAN support in 5G." These groups will inform the telecoms industry of the use cases and requirements that need to be met by the new wireless technology, particularly the level of end-to-end low latency, security, service reliability and the

ability to have application-specific network “slices¹⁶” to guarantee quality of service for different applications.

Here it is important that all stakeholders are involved in testbeds and trials seeking to find answers to these questions. Some of the organisations mentioned above are providing environments for testing specific applications and bringing the relevant parties together. The UK is funding industry-specific 5G testbeds; the manufacturing testbed is in Worcestershire and has a combination of telecoms and manufacturing industry stakeholders taking part: Huawei, O2, BT, Yamakazi Mazak, Worcester Bosch and others.

On the regulation side, there are considerations that need to be made for releasing spectrum - which bands to allocate based on different use cases. For example, millimetre wave spectrum (26-60 GHz) needs to be available to enable ultra-low latency 5G applications. Without a clear evaluation on how much spectrum is required at different bands to satisfy the needs of the manufacturing industry and the use cases they want to implement (as well as other industries), these decisions could result in insufficient capacity at some bands and underused capacity at others.

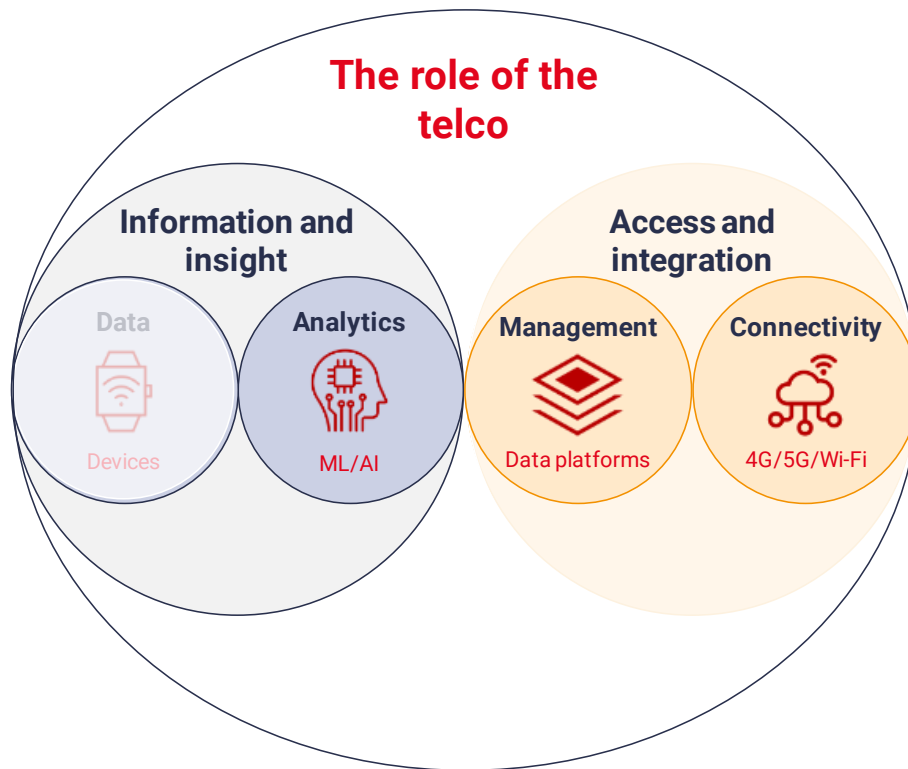
In some cases, spectrum may be ringfenced for particular (large) manufacturers in the form of a private 5G network, primarily to isolate network capacity for a single production facility and ensure reliability. There are different ways this could be delivered, which we explore in *Private and vertical cellular networks: Threats and opportunities*.

More on the role of the regulator can be found in STL Partner’s report 5G regulation: Ensuring successful industrial transformation.

Collaborate with telecoms operators

The telecoms operators themselves are starting to change their business model to ensure that the connectivity technologies they provide are used effectively across industries by collaborating with industry more closely. This is partly driven by the fact that their current business model of selling data by gigabyte is no longer delivering revenue growth, but also because they are building new skills and capabilities that address the needs of other markets. Plus, the nature of 5G means that it is not a “one size fits all” network but will be flexible to meet diverse needs. As mentioned above, this requires skills to marry the needs of a customer with the potential opinions that could be supplied. STL Partners is exploring the concept of the “Coordination Age” in detail in [our research](#).

¹⁶ Separate (virtual) networks that run on the same physical network infrastructure and are designed in unique ways to meet different needs, e.g. low latency/ultra-reliability vs. support for massive number of devices.










Figure 21: Telcos playing beyond connectivity

Source: STL Partners

This will change the relationship of the telecom operators with their partners, including manufacturers. Their primary role will still be to provide a (5G) communications network and improve access to data. However, they will do this differently (see “Network-as-a-Service” below) and may also provide other services to improve the integration and management of data, as well as the analytics and services on top. In evaluating how the manufacturing industry could collaborate with telcos, we have outlined their potential business models below and examples of two telcos (Elisa and Deutsche Telekom) playing in different domains. We cover the story behind Elisa’s Smart Factory in *Elisa’s Smart Factory: How to win over industry leaders in two years* and an evaluation of private mobile networks (as per Deutsche Telekom) in *Private and vertical cellular networks: Threats and opportunities*.

More on these new telco business models and how enterprises could seek to collaborate more effectively can be found in STL Partner’s report 1.4tn of benefits in 2030: 5G’s impact on industry verticals.

Figure 22: Telco 5G business models

| | | |
|--|--|---|
|  <p>Solutions and Applications</p> | <p>Provide custom end-to-end solutions for customers, includes consulting and advisory services, systems integration and applications</p> |   <p>e.g. 3D digital twins, predictive maintenance</p> |
|  <p>Application Enablement</p> | <p>Aggregate applications and data from multiple partners to multiple users e.g. data management & sharing, billing / transactions, app marketplace</p> |   <p>e.g. data management and integration platform</p> |
|  <p>Networks-as-a-Service</p> | <p>Manage custom networks in a cloud-like way, i.e. ability for customer to scale up and down, define parameters (e.g. latency), and add other functionality</p> |   <p>e.g. bespoke public/private networks and network slicing</p> |

Source: STL Partners

Conclusion

- In this report, we have demonstrated that 5G has unique capabilities that can be leveraged by the manufacturing industry to introduce new use cases and ultimately help the sector increase productivity and improve efficiencies, as well as transform business models more fundamentally.
- The most important characteristics that 5G brings to the industry are the ability to collect more data by connecting more devices and increasing bandwidth; ensuring data is collected reliably and securely and reducing latency to unprecedented levels in wireless technology.
- Three example use cases that will make use of these characteristics are:
 - **Advanced predictive maintenance:** collecting huge amounts of data to accurately predict when a machine will fail and reduce unplanned downtime.
 - **Precision monitoring and control:** monitoring the entire plant and its processes continuously and adapting processes in real-time to maximise productivity and reduce defect rates.
 - **Augmented reality and remote expert:** streaming high definition video and information without any latency to use augmented reality headsets to improve efficiency and support workers in maintenance tasks, operational processes and training.
- Globally, the impact from 5G on manufacturing GDP is forecasted to be \$739 billion by 2030, an increase of 4% on the base forecast, with most of the benefit (73%) in the leading manufacturing nations, such as China, USA, Japan and Germany.
- Other than contributing to industrial growth in manufacturing, 5G also has a potential socio-economic impact. The insights from increasing access to information can benefit society more broadly, whether it be to utilise resources more effectively, optimise energy use or improve health and safety.
- However, for the manufacturing industry to take advantage of the benefits of 5G, it will need to take an active role to make sure that 5G evolves quickly to include technological advancements that will support new use cases (i.e. those that require ultra-reliable low latency) and be deployed in (remote) areas close to manufacturing hubs. This includes:
 - Building an understanding of 5G and its benefits
 - Inputting into the development of 5G standards and regulation
 - Collaborating with telecoms operators

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