Industry 4.0: Maturity of Adoption and Its Impact on Sustainability and ESG

Discovery Report

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451 Research

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Market Intelligence

About this paper

A Discovery paper is a study based on primary research survey data that assesses the market dynamics of a key enterprise technology segment through the lens of the "on the ground" experience and opinions of real practitioners — what they are doing, and why they are doing it.

About the Author

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Ian Hughes is a Senior Research Analyst for the Internet of Things practice at 451 Research, a part of S&P Global Market Intelligence. He has 30 years of experience in emerging technology as a developer, architect and consultant through key technology trends.

Ian has 20 years of experience at IBM in cross-industry application development. This included automotive, global sporting events, retail and telecommunications.

Ian was early to the web development space in 1998 and social media in 2004, and was influential in virtual-worlds adoption in 2006-09. He has spent the past seven years at his own consulting company, where he presented a regular emerging technology feature on a UK Saturday morning children's TV show, built virtual disaster simulators for hospitals, pitched startups to investors, wrote a technology column for a fashion magazine and wrote two sci-fi novels. He was awarded an Honorary Doctorate in Technology from Southampton Solent University in 2018.

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Introduction

This report examines the data from a survey of more than 600 companies conducted by 451 Research and commissioned by Hitachi Vantara on the application of Industry 4.0 approaches in manufacturing, transportation and energy, to explore the maturity of digital transformation in those industries.

451 asked participants about new technology adoption, such as internet of things (IoT), artificial intelligence and machine learning (AI/ML), and digital twins, as well as perceived attitudes toward adoption of these technologies among peer companies. The survey provides an indication of which industry sectors are leading the way and the path that the remaining industries will take.

Digital Maturity: A Short Definition

The digital maturity of companies in this report refers to the adoption of instrumentation and control technology, such as industrial IoT, that will lead to analytics applications using that data. Over time, organizations will integrate additional operational technology (OT) systems with other enterprise applications and data, which will enable more advanced analytics. Once these are in place, companies can implement AI/ML-based advanced capabilities such as predictive and prescriptive maintenance and predictive quality. The operational focus can then extend to engagement with other parts of the product or service life cycle and integration with business processes, such as workforce management, field service assistance, customer usage insights, product design and continuous improvement.

Key Findings

- Of the three industries covered in the survey, manufacturing is the most digitally mature – i.e., the furthest along with digital transformation – followed by energy and transportation.
- Among surveyed companies that are already engaged in digital transformation, 57% said IT and OT are actively cooperating, suggesting there is still much room for improvement for true IT/OT data convergence synergies.
- The adoption of digital twins, while still in the early stages of development, is emerging as a significant indicator of digital maturity by which to compare industry sectors.
- Use cases with the greatest expected growth in the next two years vary by industry. Manufacturing respondents most often cited assembly line creation and optimization, while transportation respondents chose predictive maintenance and energy respondents selected smart metering.
- Shortage of skilled labor is a source of widespread worry. Companies are uniformly concerned about acquiring skills related to data science, IoT and emerging areas such as robotics.
- While security remains a key concern, respondents don't regard engineers with security skills as being in short supply. This could be partly due to increased use of AI/ML tools to assist staff, as 46% of respondents cited digital/data security as a top AI use case.
- ESG outcomes from digital transformation do not appear to be extensively driven by regulation; companies are seeking to achieve efficiency and sustainability primarily as a competitive necessity.

Assessing Digital Maturity – Peer-to-Peer Comparison

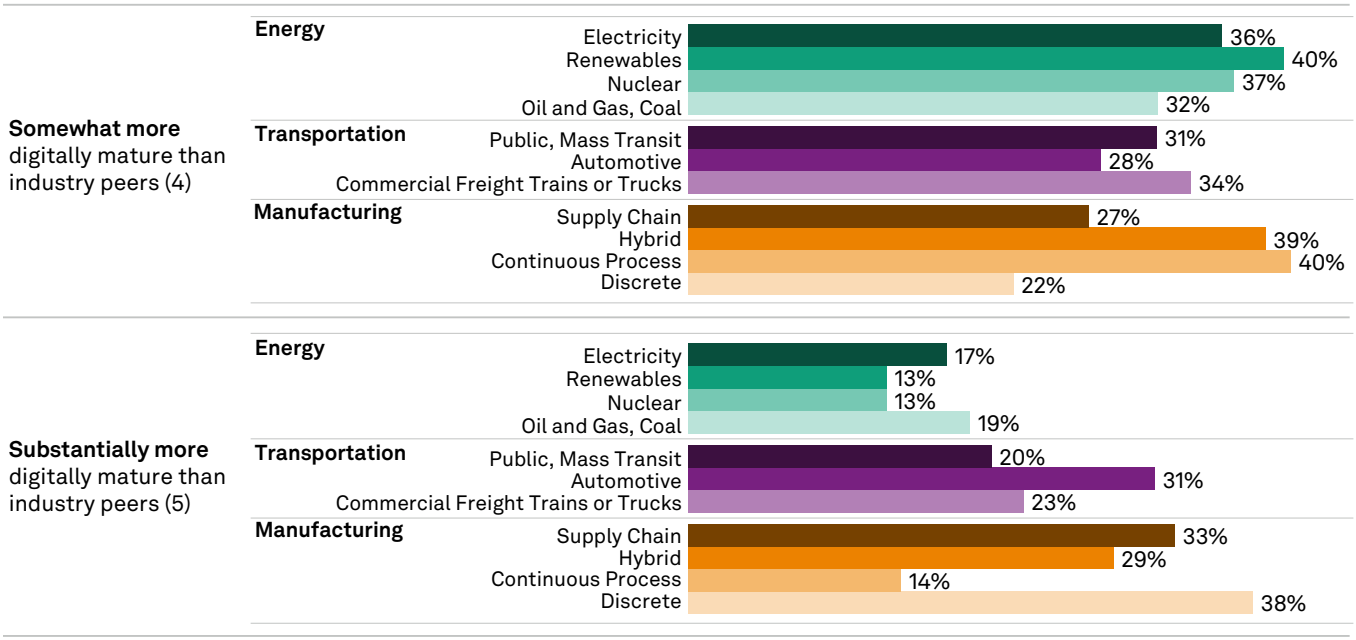
In this context, digital maturity refers to how well an organization engages digitally with stakeholders in business, OT and the front line. The term Industry 4.0 has evolved from a specific German standard (Industrie 4.0) used in discrete manufacturing to be a more general description of digital transformation of the OT environment. Industry 4.0 is the application of technology such as IoT connectivity, data gathering and control, where that IoT infrastructure in turn feeds AI/ML and data-analytics-enabled process improvements, such as predictive maintenance. Industry 4.0 approaches lead to enabling new digital industry use cases such as autonomous robotics and connected workers.

The survey's approximately 600 respondents were selected based on their affirmative answer to the question, "Is your company currently engaged in (or planning) operational digital transformation in your operations or supply chain (often described as Industry 4.0)?" Respondents were then asked to compare their company to industry peers to gain an initial indication of relative digital transformation maturity.

Overall, 21% of respondents said they are substantially more digitally mature than their peers, 32% said somewhat more mature and 33% said they are on par with peers. Only 14% rated themselves as somewhat (9%) or substantially (5%) less mature than peers.

In other words, more than half of all respondents (53%) consider themselves above average in digital maturity, and 86% rank themselves either at or above peer level. Breaking down the results by industry sector shows that some groups edge ahead in self-reported digital maturity (see Figure 1).

Figure 1: Industry Sector Breakdown: Proportion of Respondents Reporting Greater Digital Maturity Than Peers



Q. Digital maturity describes an organization's ability to engage digitally with stakeholders (e.g., business, OT and front line). Overall, how would you rate your organization's digital maturity relative to industry peers?

Base: Respondents that identify as substantially or somewhat more digitally mature (n=329)

Source: 451 Research custom Industry 4.0 survey, June 2022

While 21% of all respondents said they are substantially more digitally mature than peers, the proportion is much higher among respondents in discrete manufacturing (38%), supply chain (33%) and automotive (31%) (see Figure 1). In the "somewhat more digitally mature" category, the continuous process and hybrid manufacturing sectors scored themselves higher than average, at 40% and 39% respectively, joined by renewables, also at 40%.

It is logical that respondents in manufacturing, and in particular discrete manufacturing, rank themselves ahead of other industries in part because Industry 4.0 approaches originated in that sector. With an array of ever-evolving products being manufactured with more automation and software sophistication than ever before, there is scope for discrete manufacturers to adopt new or upgrade existing equipment and for new factories to be created based on the latest technology.

Manufacturing respondents may also view themselves as leaders in digital maturity because factory equipment is usually in a fixed location, which makes applying IoT communication to sensors easier than in widely distributed or constantly mobile hardware such as in energy and transportation. However, the renewable energy industry is also based on a greenfield application of new technology, creating a higher self-perception of digital maturity.

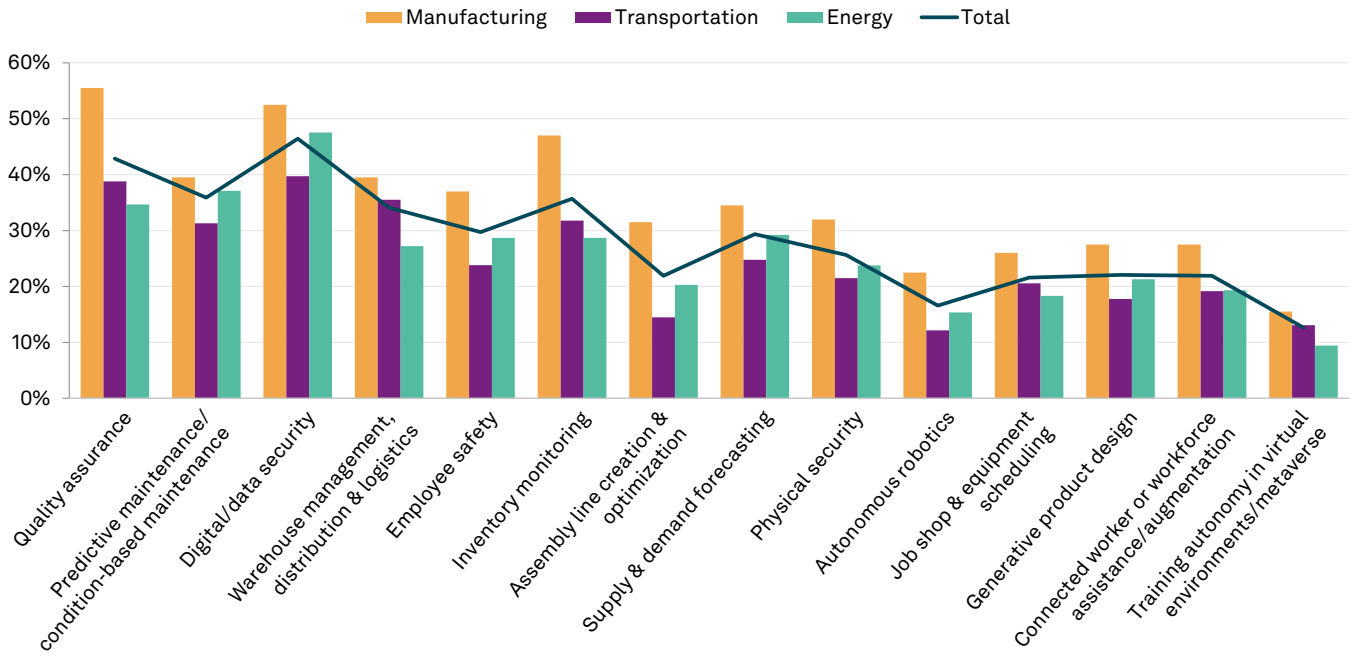
AI/ML – a Digital Maturity Indicator

Artificial intelligence refers to a set of advanced analytics that use data to derive insights needed for solving complex problems. Through techniques such as machine learning, algorithms can be formed based on large volumes of representative training data. These algorithms or models are then deployed to enable runtime processes to quickly identify significant events in subsequent live data.

Industry 4.0 gathers lots of data through IoT instrumentation and fusion with existing data systems. Industrial processes have typically logged data through historian processes, but these data sources have generally only been looked at after a significant event. Historian data is now being used as the training source for AI systems. The insights gleaned from the existing data sources provide a base for applications, such as predictive maintenance, to detect, diagnose and make recommendations based on the live data streams. AI is impacting many toolsets and applications and is often embedded in these rather than being a separate application.

The adoption of AI/ML tools in assisting processes is a natural follow-on in digital maturity because once there is enough instrumentation and data in place, AI can be applied to a use case. In the survey, we asked respondents about AI use case adoption. These different types of application provide another level of digital maturity and show a degree of difference across the three industry sectors being examined.

Figure 2: AI Use Cases by Industry



Q. Which of the following describes your operational organization's artificial intelligence or machine learning use case(s)?
Base: All respondents (n=616)
Source: 451 Research custom Industry 4.0 survey, June 2022

Manufacturing leads the three industries surveyed in adoption of AI across all use cases, with energy most often coming second and transportation following (see Figure 2). Digital/data security is the top use case across all three sectors and is, along with predictive maintenance, one of the few use cases where the energy sector is above the average and close to manufacturing.

Energy has a greater set of AI use cases than transportation because it is already a data-intensive industry. Energy, like manufacturing, has an underlying supervisory control and data acquisition (SCADA) operational layer. The data from existing operations is already used for things such as supply/demand forecasting and as core infrastructure for countries that have significant regulatory requirements and a need to preserve security, both physical and data-based.

AI use can indicate a degree of maturity, but because it is now being infused into applications, sometimes as part of a normal upgrade, it is pervasive across all sectors. Use cases such as quality assurance are more prolific in sectors such as manufacturing where a volume of product is being created, compared to sectors more focused on service-level challenges such as transportation, which creates a less definite pointer to digital maturity. However, AI is of little use without well-organized and coordinated data, and digital twins go some way toward achieving this goal.

Digital Twins/Digital Threads

Digital twin is a term describing the fusion of multiple types of data into a cohesive model, such as of an industrial plant or process. Digital twins sit well along the industrial digital maturity adoption curve, after basic IoT instrumentation, analytics and AI/ML. A digital twin can combine live IoT data mapped to an accurate visual model of the process – e.g., a 3D model of manufacturing plant machinery with IoT instrumentation data shown at its point of origin on that model.

Less complex digital twins are collections of machine data providing a current state of operation in a single place. Digital thread refers to the life cycle of a digital twin. A new facility or operation can be designed digitally, including its IoT data points. This digital twin can be used in simulations to test and improve the facility or operation. The twin then can be used as the building plan, and it eventually becomes the operational digital twin when the facility is running, creating a digital thread for the digital twin.

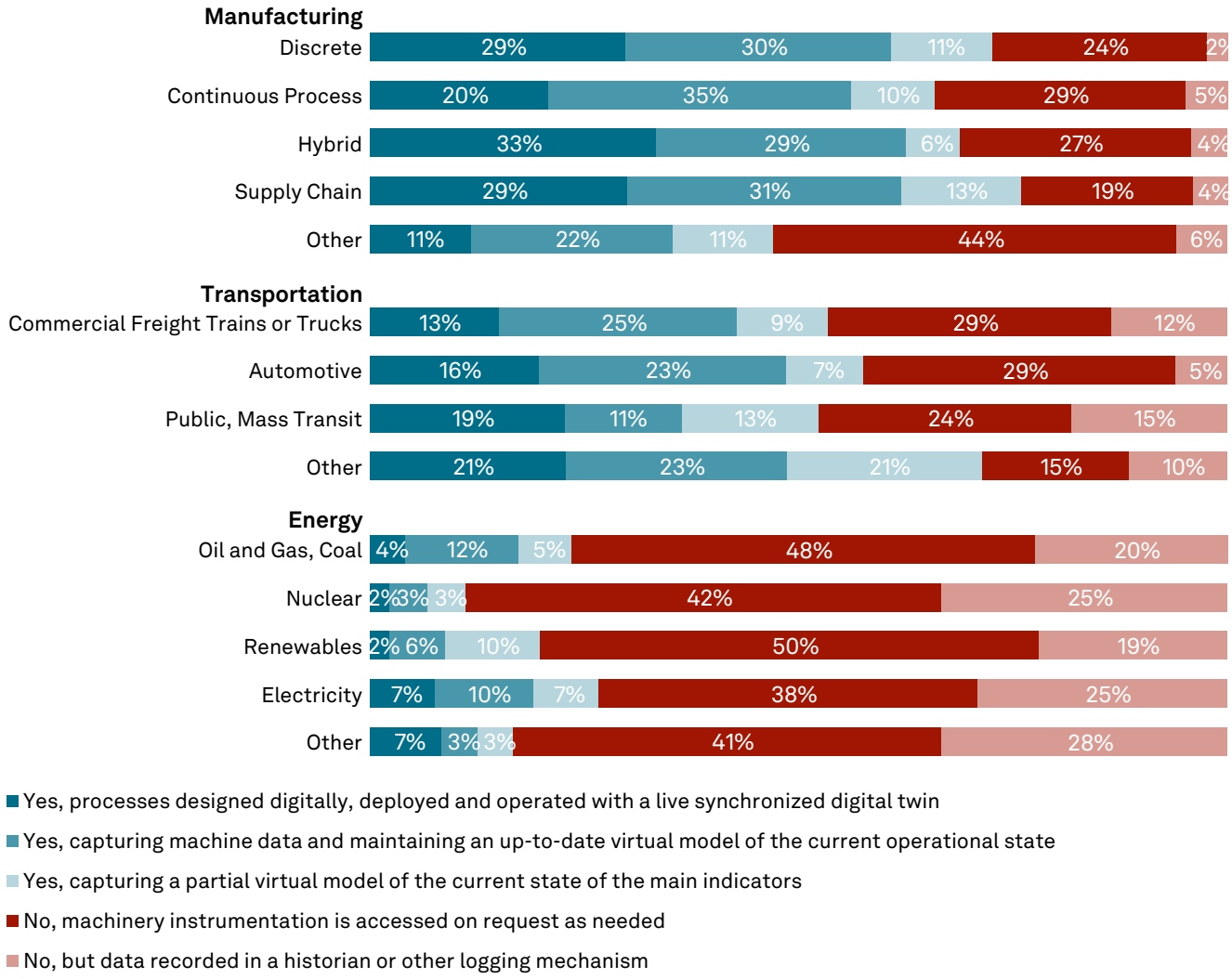
Seeding an Industrial Metaverse Future

These digital twin approaches are emerging after initial Industry 4.0 digital transformations as the complexity of deployment – and the amount of data involved – increases. Digital twins and the ability to interact with them in various ways, such as with multiple people performing tasks on them, form the core of the fledgling industrial metaverse that is under development. The industrial metaverse is envisioned to be a fully immersive virtual and augmented replica of industry processes and facilities.

Digital twin adoption, and the type of digital twin in operation, is a potential indicator of advanced digital maturity, just as IoT adoption signaled the way over the last five years. Once organizations have infrastructure in place to collect IoT sensor data and provide operational control remotely, they are then faced with a large amount of data that needs to be cleansed, (re)organized, (re)formatted and contextualized to be of use.

In an Industry 4.0 environment, a digital twin represents a move to more advanced levels of data usage for decision-making, and hence maturity of operation. If instrumentation is just read from machines as needed, that indicates less maturity.

Figure 3: Digital Twin Deployment by Industry



Q. Does your organization currently operate a digital twin and digital thread process across your operational systems today?
Base: All respondents (n=616)
Source: 451 Research custom Industry 4.0 survey, June 2022

Energy industry respondents are primarily accessing machine instrumentation as needed, or data logging to a historian, i.e., the traditional way of dealing with machinery and its data (see Figure 3). The manufacturing sector, meanwhile, has shifted toward advanced digital twin approaches. Transportation sits somewhere between the other two sectors but is on a journey toward digital twins.

Digital twins are not yet a well-defined industry standard, but the survey results showing adoption of this approach mirror the relative digital maturity scores that respondents gave their companies, with those ranked as more digitally mature also having greater digital twin implementations.

Digital twins are also at the core of developments to enable industrial metaverse applications. The adoption chain starts with IoT, followed by AI operating on that data. This base of instrumentation and data leads to use of digital twins to provide context. Digital threads are the next evolutionary step as digital twins go from design to operation. Digital twins ultimately lead to an operating environment in which the workforce can engage with the rich data – e.g., for training or to run maintenance what-if simulations, which is enabled by industrial metaverse applications.

Where IT Meets OT

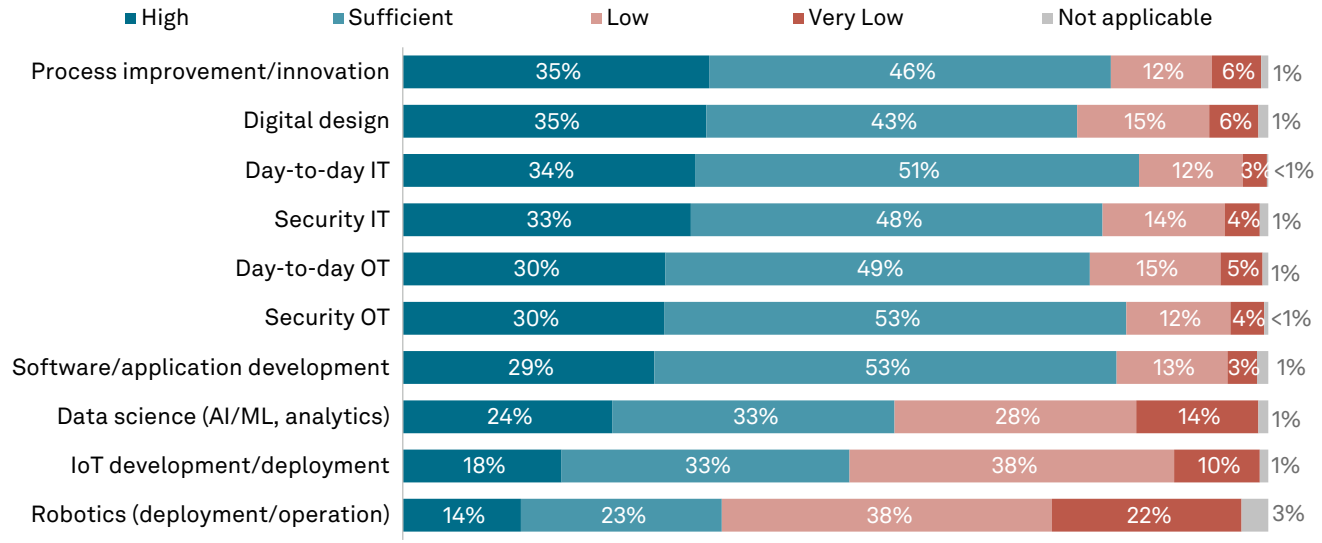
Organizational Responsibilities and Workforce Skills

New technology adoption often requires new workforce skills, and it can present organizational challenges. In Industry 4.0 transformation, IT and OT, which have previously operated separately, need to work together. Among all respondents, 57% said that IT and OT cooperate closely on IoT projects from conception to operations, and 37% said IT and OT work together on IoT projects as needed.

Departmental financial responsibility is also an important indicator. We asked what groups contribute budget for an organization's digital transformation initiatives, and the top response was IT department (70%), followed by OT (63%), with other lines of business at 31%. However, newer organizational entities such as digital business units (30%) and digital transformation/innovation office (33%) made a significant showing.

Identifying where skills are in short supply can also indicate where emerging technology is being adopted.

Figure 4: Skills in Short Supply



Q. Considering the overall capabilities within your organization, how would you rate the skill profiles for each of the following areas?
Base: All respondents (n=616)
Source: 451 Research custom Industry 4.0 survey, June 2022

Data science for AI/ML and analytics is an emerging role with skills in short supply; 42% of respondents indicated low or very low coverage (see Figure 4). Almost half of respondents (48%) rated IoT development and deployment skill levels as low or very low. Robotics deployment/operation is the least available skill set in the list, with 60% in the low or very low category. Robotics is evolving from basic industrial automation to higher-end autonomous machinery and often involves a combination of IoT and AI/ML.

In the past, security skills for both IT and OT were often considered to be in short supply. However, respondents do not see this as a major issue. Many startups have begun providing AI/ML tooling for security in the past few years, in both IT and OT. This has also led to a lot of M&A activity, with these features being rolled into the products of larger companies. Looking back at Figure 2, we can see that digital/data security is the top AI use case across all industries, indicating that advances in AI security tools, such as asset discovery and anomaly detection, are providing assistance to mitigate the need for specific skills in the space. The maturity and scale of IoT platforms and successful IT/OT projects has also helped with security readiness.

Respondents across the three industries surveyed broadly agree that there are enough people with software/application development skills. This does not highlight relative digital maturity but does indicate a transformation, reliant on software, that has already occurred in the operation of the OT industries.

Sector-Specific Use-Case Growth

The manufacturing, energy and transportation industries each have specific digital transformation use cases. We asked respondents to indicate which use cases are in use today and which they expect to see implemented in two years' time. This gives detail on technology roadmap and balances the initial self-assessment of relative digital maturity.

Manufacturing Use Cases

Use cases in manufacturing range from the basics of machine instrumentation and connectivity (IoT) to collaborative robotics and AI-generative design.

Figure 5: Manufacturing Use Cases, Now and in Two Years

Q. Within your vertical, which of the following digital transformation use cases have you implemented today?
Q. And which of the following digital transformation use cases do you expect to implement in two years?
Base: Manufacturing industry respondents (n=200)
Source: 451 Research custom Industry 4.0 survey, June 2022

In the next two years, manufacturing respondents expect assembly line creation and optimization (39%) to be the biggest area of growth. Quality assurance, production monitoring and inventory management, each in use by over 50% of respondents today, are all projected to reach nearly 90% implementation in two years.

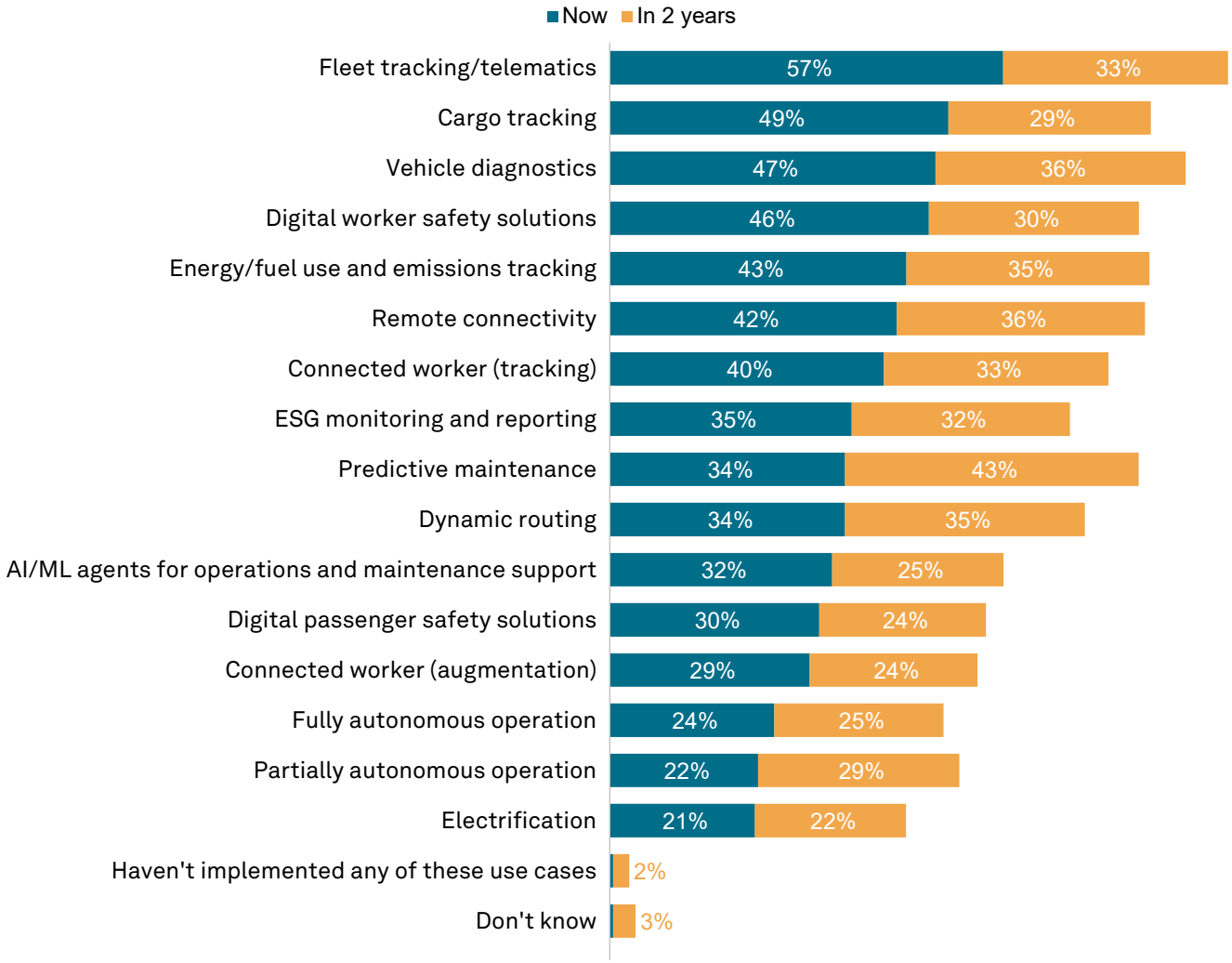
Manufacturing is evolving from high-volume, low mix to low-volume, high mix. This is possible through the digital transformation of the industry, such as assembly line creation and optimization approaches. Most companies are still dealing with the basics of production and inventory monitoring and applying quality control through faster and more detailed data gathering, but the other use cases will grow from this base infrastructure.

Transportation Use Cases

Transportation organizations deal with complex machinery that also needs to move from place to place. Use cases range from the basics of vehicle diagnostics and predictive maintenance to dynamic routing, fleet tracking and autonomous operation.

Transportation industry respondents expect that predictive maintenance (43%) will experience the largest growth in the next two years (see Figure 6). Fleet tracking already has 57% take-up, with an additional 33% in the next two years, bringing that capability to almost 90% of the industry. Vehicle diagnostics is in use for 47% of respondents, with a further 36% in two years' time. Electrification is the category with the lowest response: 21% today and a further 22% in two years. Fully autonomous operation doubles in the next two years from 24% today.

Figure 6: Transportation Use Cases, Now and in Two Years



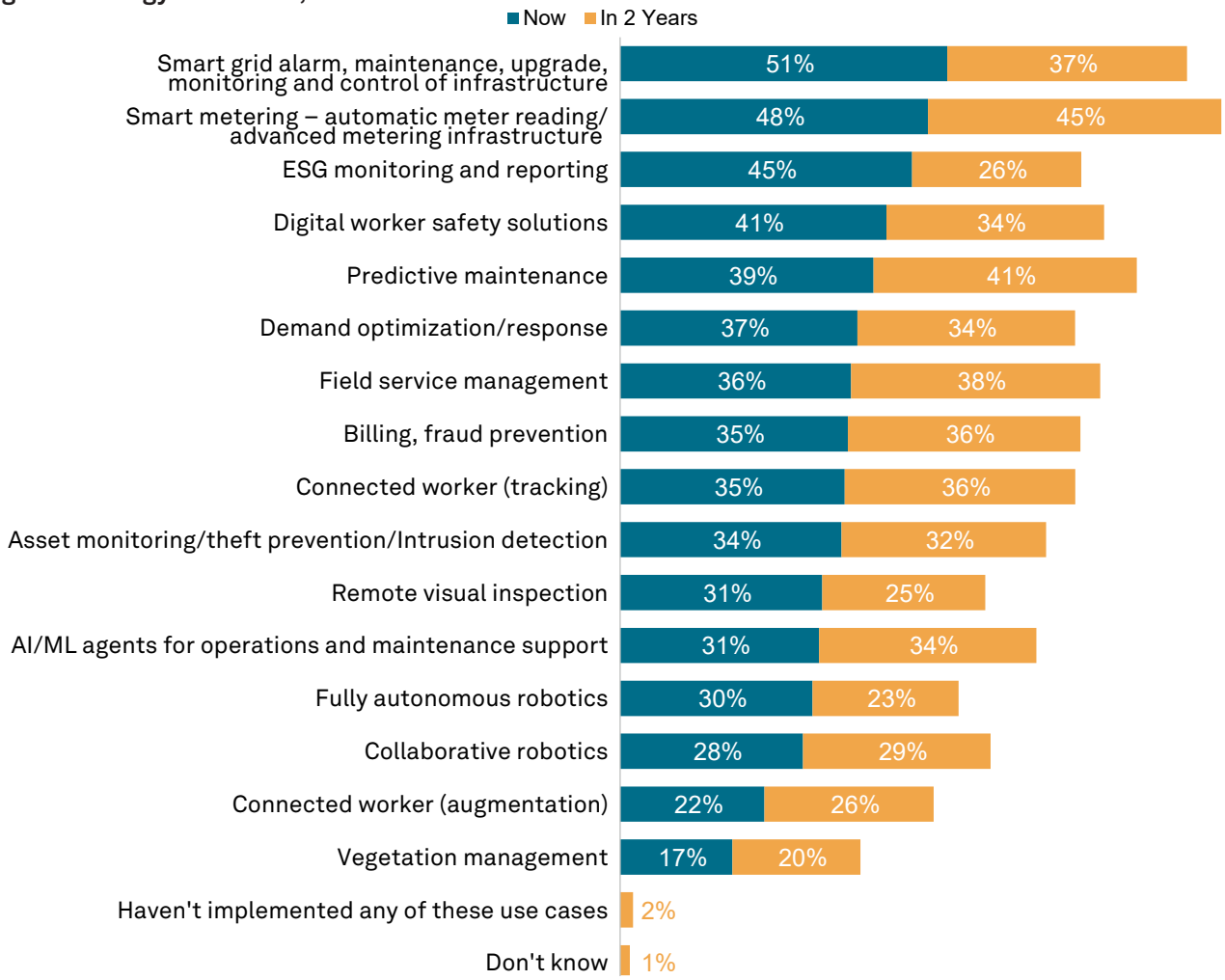
Q. Within your vertical, which of the following digital transformation use cases have you implemented today?
Q. And which of the following digital transformation use cases do you expect to implement in two years?
Base: Transportation industry respondents (n=214)
Source: 451 Research custom Industry 4.0 survey, June 2022

Knowing where vehicles are and understanding how they are performing are the obvious key use cases continuing to be adopted. Basic vehicle diagnostics while the vehicle is at a service base is being enhanced by the application of remote connectivity. Having a network connection to a vehicle leads to the growth of the other use cases. While a vehicle will have onboard computing power, the ability to communicate to a central control or to other vehicles in a fleet provides more ways to improve overall efficiency. Vehicle communication with other vehicles and with infrastructure is a key component in the development of autonomous vehicles. The data shows that fully autonomous operation is not considered a primary use case now or in two years, but it is a very complex and high-end digital transformation use case that is still developing compared to the more well-established basics of vehicle operation and monitoring. Fuel use and emissions monitoring is in the top group of use cases; electrification has the lowest response rate, but regulatory pressures may affect this balance in the future.

Energy Use Cases

Use cases for the energy sector range from smart metering and smart grid management to field service management and remote visual inspection.

Figure 7: Energy Use Cases, Now and in Two Years



Q. Within your vertical, which of the following digital transformation use cases have you implemented today?
Q. And which of the following digital transformation use cases do you plan to implement two years?
Base: Energy industry respondents (n=202)
Source: 451 Research custom Industry 4.0 survey, June 2022

The energy sector will remain focused on smart metering, with this category totaling over 90% coverage in two years' time. Smart grid is also a key use case for the industry, with 51% today and 37% adding it in two years. Predictive maintenance (80% combined, now and in two years) and field service management (74% combined, now and in two years) are the next key use cases. ESG monitoring is used by 45% of respondents' organizations today, behind only smart metering and smart grid.

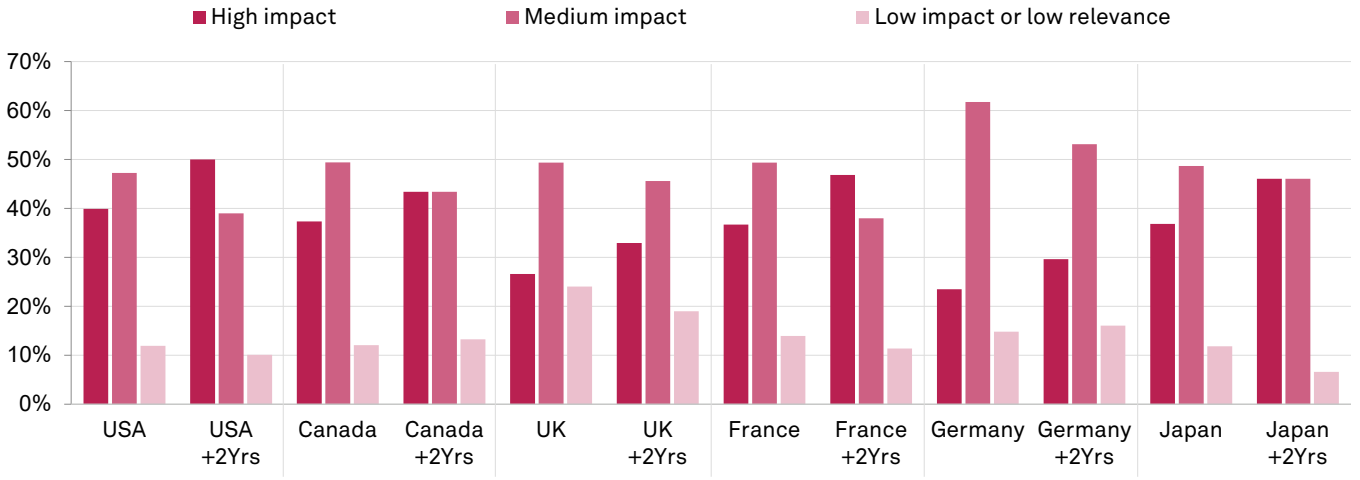
Energy infrastructure, such as the electrical power grid, is undergoing a dramatic change as power generation becomes more distributed through new renewable energy deployments. Hence smart grid is the biggest use case today. Closely related to this is understanding how much energy customers are using and when through smart metering. However, the sheer volume of locations smart meters need to be installed, including in houses and businesses, makes it difficult for the industry to keep up with the rapid evolution of IoT and connectivity approaches. At least in part, the size and scale of the potential transformation is causing energy to appear less advanced in its digital maturity than the other sectors.

Environmental, Social and Governance (ESG) Regulatory Impact

For many companies, ESG goals are becoming increasingly important. Customers, shareholders and staff are pressuring companies to perform better regarding environmental and social impacts. Regulations are being put in place to adjust company behavior, too. In the industry-specific use case questions (Figures 5, 6 and 7), ESG monitoring and reporting, now and in two years' time, shows totals for manufacturing at 62%, transportation at 67% and energy at 71%. We asked respondents what the relative impact of ESG regulations are today and what they are expected to be in two years and looked at potential variation across countries.

Figure 8: ESG Regulatory Impact, Now and Future, by Geography

Q. How do you see the impact of ESG regulatory requirements on your organization today?



Q. How do you see the impact of ESG regulatory requirements on your organization in the next two years?
Base: All respondents (n=616)
Source: 451 Research custom Industry 4.0 survey, June 2022

Very few respondents in any of the countries surveyed see ESG regulatory impact as having low relevance. However, the data shows only a slight shift from medium to high impact over the next two years due to ESG regulations. About 30% of respondents in the U.K. and Germany indicated that regulation will have a high impact in two years, compared to about 40% of respondents from Canada, and closer to 50% of those in the U.S., France and Japan.

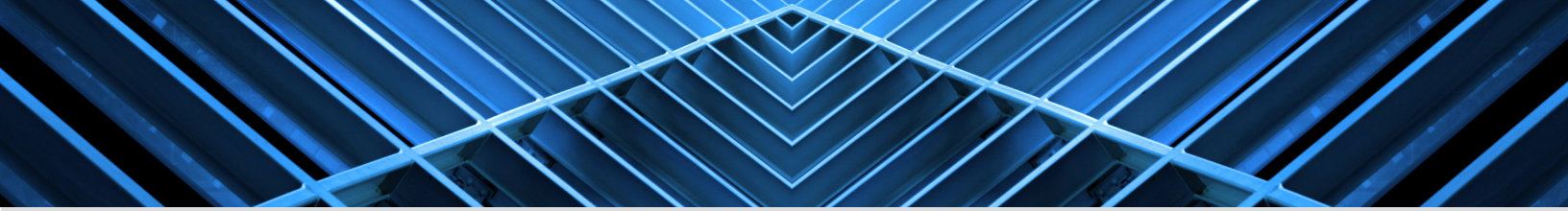
While regulation will have some impact, companies indicated that the primary drivers to meet ESG goals are coming from other market and social pressures. Increased efficiency and sustainability is a competitive factor for enterprises. Digital transformation helps make these efficiency improvements, and many of the ESG requirements achieved are almost a bonus. When a manufacturer can maintain a piece of machinery more efficiently – such as with predictive maintenance enabled by IoT instrumentation (a key step in the digital maturity path) – it will also likely use energy and raw materials more efficiently and, therefore, will be less likely to suffer a dangerous failure. In addition, IoT monitoring provides data for regulatory requirements.

Conclusions

- The perceived level of digital transformation maturity compared to peers parallels the use-case adoption and the growth in the use of digital twin concepts. The evolution of this technology is toward real-time digital twin interactions for the workforce.
- The basics of IoT instrumentation and monitoring need to be in place before richer and more valuable use cases can come into play. The maturity of an industry's core IoT infrastructure determines the next steps, but once in place, there are a plethora of opportunities to improve efficiency and find new approaches to markets.
- Cooperation between IT and OT is increasingly the norm, and this is essential. New digital transformation units are forming and becoming responsible for delivery in about a fifth of respondents' organizations.
- AI/ML requires the skills of data scientists, which are in short supply.
- Security is an ongoing concern and will remain so, but the deployment of new AI/ML-powered security tooling may have helped mitigate what would otherwise be a shortage in IT/OT digital security skills.
- AI features in all industry sectors. Because AI is embedded in a growing array of tooling and processes, it is having an impact not only on more digitally mature industries, but also on those that are lagging. As an underlying technology, AI is becoming business as usual, and thus, it is not a predictor of digital maturity in the same way that digital twins are.

Methodology

This global survey conducted in June 2022 focused on understanding the state of Industry 4.0 adoption and related technology approaches, as well as the challenges in scaling these from proofs of concept to full operational digital transformation. The study included about 600 respondents from Canada, France, Germany, Japan, the U.K. and the U.S. Target respondents included purchase decision-makers for Industry 4.0 digitization initiatives for both operational technology (OT) and information technology (IT). Respondents' industries include manufacturing (including discrete and continuous process and supply chain), commercial transportation (including public mass transit infrastructure and fleet management and logistics) and energy (with emphasis on utilities power generation and distribution).



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This report, conducted by 451 Research and sponsored by Hitachi Vantara, highlights some key findings about the state of Industry 4.0. The data shows that the importance and imperative of this digital transformation is well understood and most companies are currently executing on their transformation. The recent pandemic and the volatile nature of current business and political environments also underscores the need to be agile and resilient, a goal that can only be achieved by digitalizing the business end-to-end. Important to recognize is that Data is the connective tissue and the big enabler, but it's also a big challenge to fully implement data-driven strategies across IT and OT.

Respondents to the survey indicated good progress but also highlighted several particular areas where they think they lack skills in their organizations to make a successful transition to Industry 4.0: Data science, IoT, Robotics and AI/ML. They also brought forward particular use cases that are important to them: digital twins, predictive maintenance, assembly line optimization in manufacturing, smart metering for utilities and an increasing focus on reporting ESG metrics across the board.

It's where the gaps are largest where Hitachi Vantara can provide the most value as a trusted partner to guide and accelerate the digital transformation. For over a hundred years, Hitachi has built and instrumented OT equipment in multiple industrial verticals and is now on the forefront across many key areas: from self-driving electric trains and self-driving car equipment to robotics, from asset management systems for power equipment to energy metering and control systems, from IoT-enabled smart agriculture to smart city solutions. Combined with over 60 years of expertise in IT and data management infrastructure, computing and storage systems with accompanying software and professional services, IoT, big data analytics and vast AI/ML development abilities, Hitachi Vantara can offer the consulting services as well as the IT and OT-domain-specific expertise to help guide businesses through their successful journeys to data-driven industrial operations.

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