Industry 4.0: How Cisco is Enabling the Future of Manufacturing

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Contents

Executive summary

Today's manufacturers face a number of challenges. These include:

- Productivity: Doing more, with fewer resources at lower cost.
- Innovation: Driving improvements in production, introducing new business models, and faster introduction of new products and services.
- Customer service: Meeting, and exceeding, customer needs at the optimum cost.
- Competitiveness: Meeting the challenge of a globalized economy.

From these challenges, Industry 4.0 (I4.0) was born in Germany and launched in 2011. It refers to the introduction of a fourth Industrial Revolution in the manufacturing sector, the fusion of the cyber and physical worlds to drive value and competitiveness in a global marketplace.

Utilizing the four design principles of interoperability, information transparency, technical assistance, and decentralized decision-making and building on the nine pillars of big data, augmented reality, simulation/digital twin, Internet of Things, cloud computing, cybersecurity, systems integration, additive manufacturing, and autonomous systems, factories can be transformed to meet future needs.

The journey to I4.0 will not be smooth; there will be many issues to overcome such as security, adoption, connectivity, standardization, and the aging workforce. However, the biggest challenge will perhaps be that of dealing with legacy systems. Systems that have been working successfully for many years.

For that reason, I4.0 should be seen as a multiyear journey. Indeed, some predict that I4.0 will take until 2030 to be fully realized. It is a journey that needs to be carefully planned, funded, and executed to derive the fullest benefits.

However, failing to embrace I4.0 could lead to lack of efficiency and competitiveness and, ultimately, failure.

Underpinning I4.0 will have to be a secure, reliable, and robust communications infrastructure to ensure that machines, sensors, and people can connect in the most effective way.

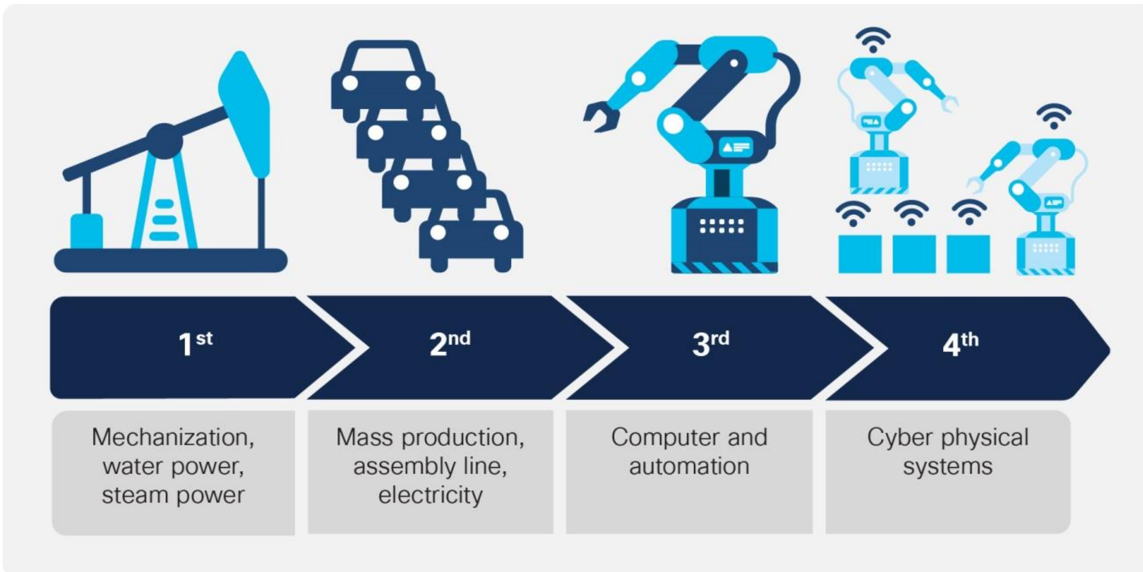
At Cisco, we believe that we have many solutions that can help manufacturers realize, and accelerate, their I4.0 ambitions.

Introduction

In 2011, at Hannover Messe, professor Wolfgang Wahlster (director and CEO of the German Research Centre for Artificial Intelligence) gave a keynote speech to the opening session. His key theme was how German manufacturers could be more competitive in global markets through better use of information technology and the Internet. The term he used to describe this future was Industrie 4.0 (I4.0) and so the fourth Industrial Revolution began.

Mankind has been manufacturing since the dawn of time but there have been three distinct periods of disruption and change:

Figure 1. The four Industrial Revolutions



- The first Industrial Revolution was in the late-eighteenth century through the mechanization of manufacturing using first water and then steam. This presaged the era of the large manufactory rather than the artisan establishments that had gone before. Improvements in transportation allowed goods to be manufactured in one location and traded in another.
- The second Industrial Revolution was the move to scientific management and mass production in the late-nineteenth and early-twentieth centuries, driven by men such as Frederick Winslow Taylor and, particularly, Henry Ford.
- The third Industrial Revolution of the late-twentieth century introduced the use of computers and automation. The development of Programmable Logic Controllers (PLCs) and advanced machinery reduced the need for hands-on human interaction. Instead, the machine could be programmed to carry out tasks independently.
- Now we have the fourth Industrial Revolution, merging the cyber and physical worlds.

It is worth noting that I4.0 was initially a political and economic measure by the German government to protect its manufacturing base, which accounted for approximately 25% of GDP, in the face of increased globalization and competition.

In the 1980s many developed countries had decided to move to a service-based economy, leading to a decline in the manufacturing base. This was exacerbated by the trend in the 1990s to offshore manufacturing to “low-cost” economies. In the United Kingdom, for example, manufacturing as a percentage of GDP fell from 27% in 1970 to 10% in 2017. The financial crash of 2008 forced many countries to rethink economic policy and look again to manufacturing.

As a consequence, since 2010, there has been a trend to reshore higher value and specialist manufacturing activities. Reshoring has provided the opportunity to invest in new tools and techniques as advocated in I4.0.

Since 2011, many countries have adopted, or adapted, I4.0 for their own purposes. Indeed, many countries will give tax relief or credits for I4.0-related projects as a means of stimulating innovation.

What exactly is I4.0?

The underlying premise of I4.0 is the bringing together of cyber and physical systems, automation, the Internet of Things (IoT), and better vertical and horizontal integration.

Hermann, Pentek, and Otto have identified four design principles for I4.0.

- **Interoperability:** The ability of machines, devices, sensors, and people to connect and communicate with each other via the IoT or the Internet of People (IoP).
- **Information transparency:** The transparency afforded by I4.0 technology provides operators with vast amounts of useful information needed to make appropriate decisions. Interconnectivity allows operators to collect immense amounts of data and information from all points in the manufacturing process, thus aiding functionality and identifying key areas that can benefit from innovation and improvement.
- **Technical assistance:** First, the ability of assistance systems to support humans by aggregating and visualizing information comprehensively for making informed decisions and solving urgent problems on short notice. Second, the ability of cyber-physical systems to physically support humans by conducting a range of tasks that are unpleasant, too exhausting, or unsafe for their human co-workers.
- **Decentralized decisions:** The ability of cyber-physical systems to make decisions on their own and to perform their tasks as autonomously as possible. Only in the case of exceptions, interferences, or conflicting goals are tasks delegated to a higher level.

The nine pillars of I4.0

There are nine accepted pillars involved in building I4.0. These are:

Big data

Organizations are, or can be, creating huge volumes of data that are not being exploited. This data can be used to unlock value for business improvement and growth.

Augmented reality

Providing additional visual data to workers to help enable process and product improvements. An example would be the use of connected glasses to help operators fit components correctly. Taking it to the next level, virtual reality allows testing of things like ergonomics without building physical representations.

Simulation/digital twin

Trialing new ideas in the virtual world can be more cost-effective than building physical prototypes. An example here is mocking up production lines/processes on a CAD system to test before a live deployment.

Internet of Things

The rapidly growing field of Internet-connected devices developing new data (for example, deploying sensors for asset condition monitoring or energy usage). The key benefit of IoT is not so much the sensors themselves but in the data that they create. I4.0 can turn that data into actionable value.

Cloud computing

The use of, often, third-party hosting services to reduce cost and complexity while offering flexibility and scalability. An example here might be the use of cloud compute services for periodic test workflows rather than building in-house server infrastructure.

Cybersecurity

All these new interconnected systems must be adequately secured against unwarranted intrusion. This could include enhanced firewalls, malware detection, and segmentation of networks.

Systems integration

Better connectivity of systems and hardware to be used together to drive increased value.

Additive manufacturing

The use of 3D printers to make components faster, lighter, and cheaper. Additive manufacturing could also be of use in maintenance and repair operations, where a replacement part could be made locally rather than shipped from source.

Autonomous systems

Technology such as robotics and artificial intelligence have developed to the stage where systems can operate independently on tasks without frequent human interaction. This could be manufacturing machines themselves or delivery platforms within the factory such as autonomous vehicles.

What are the challenges facing manufacturers and how can I4.0 help?

Manufacturers face a number of challenges in global markets.

Productivity

The first major challenge is productivity: how to do more, faster, using fewer resources. Factors affecting productivity include:

Factor	Impact	Solution	I4.0 pillar/s
Machine reliability	Equipment failure stops production	• Asset condition monitoring • Proactive maintenance • Use maintenance windows • Reduce plant disruption	• Internet of Things • Big data • Cloud computing
Machine utilization	Inefficient use of plant and machines	• Product line optimization • Production planning • Machine-machine communication	• Systems integration • Big data • Augmented reality • Autonomous systems • Digital twin
Line reconfiguration	Plant shutdown time during refit	• Computer modeling and planning	• Augmented reality
Defect detection	Rework required at cost	• Automated processes • Augmented reality to help workforce	• Augmented reality • Autonomous systems
Energy management	Unnecessary expense	• Energy monitoring and management	• Integrated systems • Autonomous systems

Innovation

The second major challenge is driving innovation:

Factor	Impact	Solution	I4.0 pillar/s
Faster time to market	Lost market share	• Computer simulation • 3D manufacturing	• Augmented reality • Digital twin • Additive manufacturing
Identify and implement innovation	Being left behind by competitors	• Learning organization	• Big data
Supply chain visibility/traceability	Increased stockholding or stockouts	• Supply chain integration	• Big data • Systems integration

Customer service

Enhanced customer service:

Factor	Impact	Solution	I4.0 pillar/s
Improved customer response time	Improved customer satisfaction	• Remote asset condition monitoring	• Internet of Things • Autonomous systems • Big data
Improved Mean Time To Repair (MTTR)	Improved customer satisfaction	• Remote expert	• Big data • Internet of Things • Additive manufacturing • Systems integration
Customization	Improved customer satisfaction	• Use customer data to tailor offering to needs	• Big data • Systems integration

What are the obstacles to I4.0?

Security

A key concern of manufacturers as they embark on the I4.0 journey is security. This includes both cyber and physical security.

Companies are concerned about:

- Theft of Intellectual Property Rights (IPR)
- Theft of customer data
- Machines being hacked and/or held to ransom

These fears have been increased by well-publicized attacks on manufacturers and the imposition of legislation in some jurisdictions concerning data loss.

Connecting machines and systems increases the attack surface and the (relative) ease with which they can be attacked. Since 2010 there has been an increase in malware specifically targeting industrial systems in addition to those targeting the traditional compute environment.

Use of cloud services introduces new threats to customer and proprietary data and introduces the potential problem of data sovereignty.

Security of operational networks has, largely, been ignored at the expense of continued manufacture. Production systems are designed for the process first, everything else second. As a result, it is not uncommon to find insecure networks with few defensive measures on the plant floor.

In the past it was considered sufficient to "air-gap" the system, with no connectivity between the plant floor and the enterprise network. In practice this was a myth; there were always other ways to infiltrate the plant floor, but it's a persistent myth. At best, a firewall was introduced between OT and IT networks.

Clearly, introducing I4.0 forces a complete rethink of both plant floor security and plant/enterprise integration.

It also forces a rethink of the physical security posture in terms of access control and plant visibility through CCTV systems.

Adoption

The second challenge is adoption. Increased automation poses a potential threat to the existing workforce that needs to be managed. Many workers can be refocused on higher value activities, but it is inevitable that I4.0 will result in workforce reduction.

In turn, I4.0 demands a more skilled workforce. This potentially means having fewer skilled resources covering a greater physical (and potentially geographic) area.

This will drive a need for increased, and improved, collaboration and communication systems to support both front-line manufacturing and second-line support functions.

Connectivity

Connecting machines and systems, deploying IoT sensors, and delivering new communication and collaboration tools within the plant will drive a requirement for highly reliable (and secure) networks across the factory.

This will necessitate both wired and wireless technologies being deployed.

Standardization and legacy systems

Implementing I4.0 will require many disparate systems to be able to connect and communicate. At present there are many competing standards.

I4.0 will not happen overnight, which means that some means of interoperability needs to be developed to allow data from system A to be ingested by system B, even though they are different.

This implies that I4.0 will be a long-term evolution and an interim stage of system brokers, or middleware, will be required in the short to medium terms.

The skills gap

Perhaps less of a challenge and more of a driver, manufacturing (and industrial sectors in general) are suffering from a double problem of an aging workforce and a struggle to recruit and retain young workers.

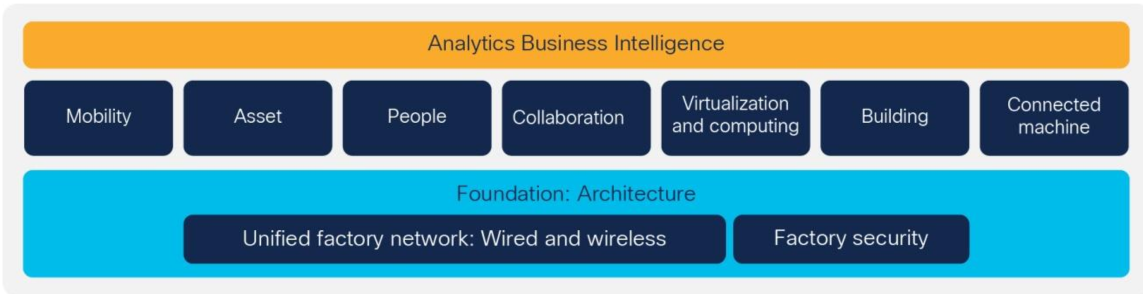
This means a need for effective knowledge capture, management, and transfer along with, potentially, better collaboration tools to provide expert knowledge where it is needed.

There is also need for closer integration between process engineers and IT engineers. Each will have to learn and appreciate (if not fully understand) the other's domain to be successful.

How can Cisco support manufacturers on the I4.0 journey?

Cisco believes that the factory of the future must incorporate a number of elements to support I4.0. This is shown in Figure 2 below.

Figure 2. The Cisco I4.0 block architecture



Solid foundations: Network and security

Underpinning any successful factory implementation will be a secure, reliable, flexible, high-performance network infrastructure that comprises both wired and wireless technologies.

Wireless will become increasingly important for workforce mobility and collaboration, location-based services, autonomous guided vehicles, sensor cloud deployment, and many other use cases.

Cisco has published a number of Validated Designs (CVDs) for factory networks and factory security. These are freely available at https://www.cisco.com and provide detailed information to design and build networks that are aligned with recognized industrial standards such as ISA95 and ISA99/IEC62443.

The networking CVD covers such design considerations as reliability and resilience, protocol support, templated designs, and management.

The security CVD includes segmentation, network admission control, role-based access control, and secure remote access.

Written in partnership with Rockwell Automation, these CVDs have been implemented in numerous factories, including those of GM, Continental Tires, Boeing, SugarCreek, and CampoFrio.

In the future, another key requirement will be orchestration and automation via the network. This will enable centralized, policy-based control of segmentation, malware/AV detection, Quality of Service/Quality of Experience, content filtering, and software-defined access to the network.

A further foundational aspect is risk assessment and management: robustly identifying and quantifying risk and deploying and managing mitigation tools.

These foundational layers facilitate higher order functionality as follows:

Mobility

Mobility means deploying new systems for product and tool traceability, workforce enablement, and collaboration.

Enhanced mobility leads to faster tracking of material and people within the plant and faster time to restore/repair service through video analytics (remote expert).

Cisco has worked with Subzero to improve time to implement new products and drive hard savings in implementation costs.

Assets

This delivers real-time asset visibility and condition monitoring, improved utilization, and inventory accuracy when linked with track and trace.

Cisco has worked with Continental Tires to track carriers within the plant and with Fanuc to provide asset condition information of robot arms.

People

Enabling people tracking can enhance safety within the plant (lone worker, work at height, and so on). It can also control access to and the flow of people around the plant.

Cisco has worked with oil and gas as well as mining customers on these examples.

Collaboration

Improved collaboration allows for more efficient use of human resources within the plant by providing rapid access to expert knowledge.

It can also facilitate intermachine communication or machine visibility in natural language.

Cisco has experience in this area with various mining customers and with Coca-Cola.

Virtualization and computing

I4.0 will create vast amounts of data that needs to be stored, analyzed, and managed. It will require high-performance data center infrastructure and management. High-dependency applications will need monitoring and optimization tools.

At the opposite end, compute resource can be deployed at the edge of the network to perform initial analysis and triage. This negates some of the northbound data and provides local analytics.

Buildings

A significant part of manufacturing costs is that required to operate the building with light, heating, cooling, and so forth. Energy management solutions can be deployed to provide visibility and management of these elements to optimize usage and cost.

Cisco has worked with Flextronics to enable these capabilities.

Connected machines

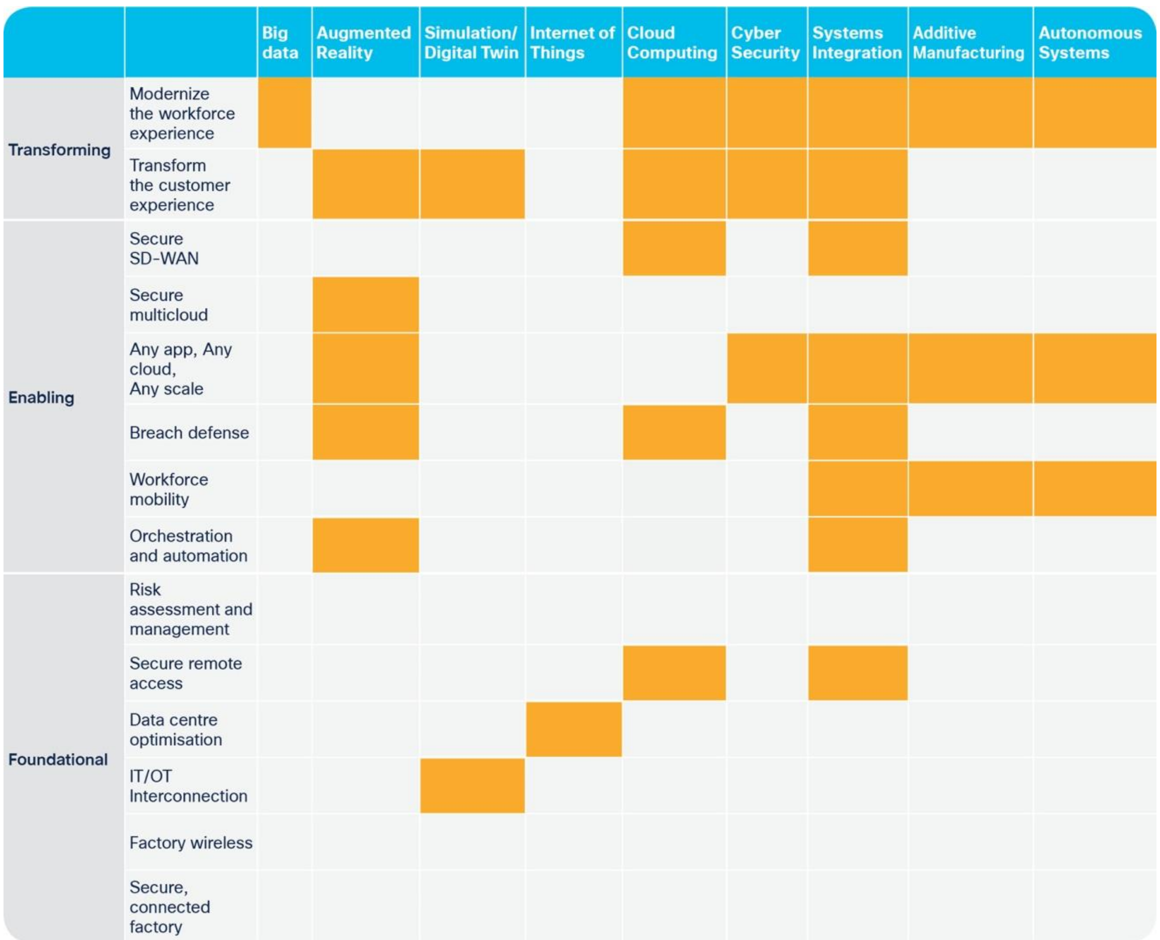
Related to several areas above, this is enabling machines to self-report problems in advance, for operators to get visibility of machine operating parameters and be able to improve utilization and uptime.

Cisco has worked with Fanuc and GM on an example of this project.

Cisco alignment with I4.0

Cisco has numerous solutions that support the nine pillars of I4.0. This mapping is shown in Figure 3 below.

Figure 3. Cisco solution mapping



The challenge of legacy

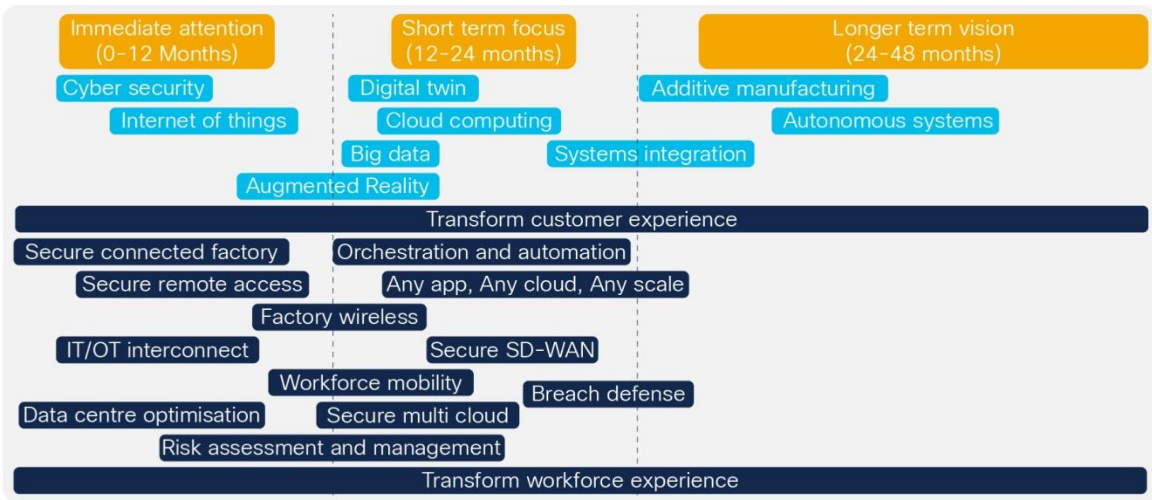
I4.0 cannot happen overnight for many customers due to challenges of legacy. Many plant floor networks were deployed more than 10 years ago and will need to be refreshed. Existing machinery may not be capable of being upgraded and integrated into an I4.0 infrastructure immediately.

Therefore, Cisco sees I4.0 happening over a multiyear timescale. Some analysts have suggested that I4.0 will not be fully realized until sometime between 2025 and 2030. In practice, manufacturing is somewhere between I3.5 and I3.8. In some pillars, technology is still nascent and not fully developed.

Many manufacturers are at the stage of proofs of concept or value to see how I4.0 best works for them. Others need to consider outside factors. In the United Kingdom, for example, there is discussion about the "productivity paradox": How can a country that works longer hours than its immediate competitors be less productive? Is it down to material or human factors, or a combination?

As a result, Figure 4, below, illustrates a potential factory upgrade timeline and an indication of the order of deployment. The exact timeline will depend on the individual manufacturer's ability to deploy, integrate, and adopt new technology.

Figure 4. Potential I4.0 timeline



Summary and conclusions

I4.0 will deliver significant change into the world's manufacturing base. It will drive greater productivity through the introduction and use of new technologies in novel ways.

I4.0 presages the coming of the autonomous connected machine that can negotiate and make decisions with fellow machines, without human intervention, to optimize production.

In principle, I4.0 should reduce the time to introduce new products and to effect changes to existing products. In turn, this is likely to reduce product lifecycles.

Automated and flexible manufacturing systems facilitate greater product customization, something that has already been seen in the automotive Industry. Henry Ford is famously (mis) quoted as saying that "the customer can have any color as long as it is black." Contrast that with Mini or Fiat today, where there are up to "a million" permutations of color and trim.

I4.0 will have a profound effect on the future of the workforce, necessitating a need for upskilling workers but, potentially, needing fewer of them. This will be particularly interesting in certain markets where the majority of manufacturers are in the Small and Medium Enterprise (SME) category (Germany's Mittelstand, for example).

Implementing I4.0 will create many challenges for existing manufacturers that have to upgrade legacy infrastructure and provide opportunity (and maybe even encouragement) for new market entrants. As an example, at least one Middle Eastern country sees manufacturing as a way to diversify and reduce dependence on oil revenues.

The risk of failing to adopt at least some of I4.0's ideas includes becoming less competitive and falling behind in the global market, potentially leading to business failure.

Regardless of the macro effects of I4.0, it is clear that the underlying requirement will be for a reliable and resilient, flexible and highly secure wired and wireless network as well as for enhanced and optimized data centers, whether onsite or in the cloud.

Cisco has the reach, vision, architectures, solutions, products, and partners to help manufacturers worldwide realize their I4.0 ambitions.

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