Overcoming Roadblocks to Industry 4.0

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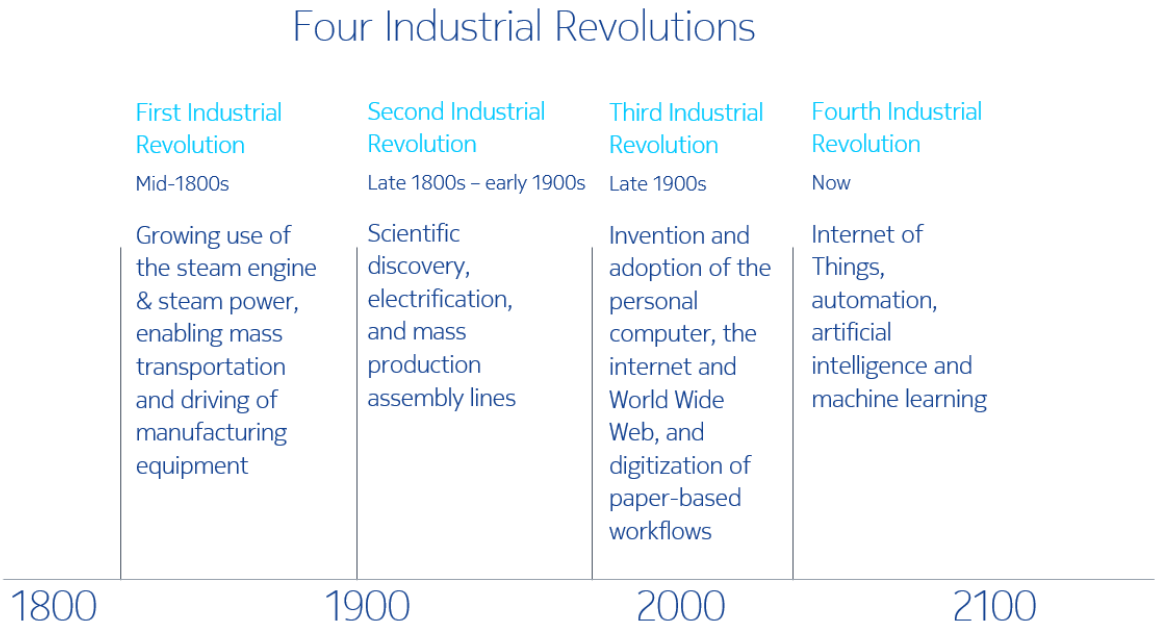
This research report by Parks Associates, together with Nokia, investigates the challenges of successfully deploying technologies for Industry 4.0. It investigates why companies in the manufacturing, energy, and transportation industries may run into roadblocks in their deployment of Industry 4.0 technology, and how they can best address their unmet needs to realize the promises of Industry 4.0.

This research is based on the results of interviews with 30 executives across the globe, with interviewees in the manufacturing, mining, oil and gas, power distribution, renewables, trucking, passenger transport, air freight, and rail industries. It presents views from major global regions including North America, Latin America, Europe, the Middle East, and Asia Pacific, including countries such as the United States, India, and China.

Industry 4.0 Introduction

Companies across the globe are turning to new technologies to streamline their business processes, improve efficiency, improve safety, and gain insights into their ongoing operations. This fourth industrial revolution, also termed Industry 4.0, is distinct from earlier changes in the workforce and operational processes through its heavy emphasis on connected devices, large scale machine-to-machine communications, artificial intelligence and machine learning, and automation.

Each implementation of Industry 4.0 is largely unique, specific not just to the industry but also to the unique needs and specific business processes of each company. Nevertheless, there are common threads that run through these deployments – in terms of their use cases, the common best practices for planning and deploying these solutions, and the common roadblocks and challenges companies experience moving forward.



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Industry 4.0 Roadblocks: Executive Summary

When it comes to implementing Industry 4.0 projects, companies may experience roadblocks that hinder their ability either to deploy technologies or to maximize the benefits of their deployments. Roadblocks range from the technical and logistical to regulatory and environmental, and even to the people and processes at work.

Executives and key decision makers across thirty companies have shared the roadblocks they have experienced, as well as their best practices and the lessons they have learned from their deployments of Industry 4.0 technologies. These shared experiences can guide executives' thinking around operational technology deployment and strategy, outlining a path to the future that avoids roadblocks and errors.

Top Roadblocks to Industry 4.0

1. **Networking Capabilities and the Operating Environment.** Industry 4.0 is built on connectivity – from the edge, through the network, to the cloud and back again. A network is essential in enabling new solutions and providing visibility into processes. Different use cases have different requirements for networking, and the company's operating environments may introduce challenges that impact companies' selection of networking technology. Companies must select their network architecture carefully.

2. **Data Silos and Data Availability**. In order for data to be actionable, it must be gathered into a centralized system for processing. Data silos continue to be a challenge, with legacy systems oftentimes requiring integration into new company architectures and centralized systems. Companies are increasingly moving processes and workflows into the cloud, allowing them an organization-wide view and control. Industry 4.0 solutions offered by vendors must be integrated back into these centralized systems, and with each other.

3. **Cybersecurity and Cyber Threats**. As industries increasingly digitalize, a strong emphasis on cybersecurity has become critical for companies. Cyberattacks have caused operational hazards for companies making use of connected operational technologies, and security concerns have delayed many companies' move to the cloud. Companies must carefully consider their cloud strategies, making use of private cloud and hybrid models when appropriate, and work to enact best practices with regards to networking infrastructure and the deployment of operational technology (OT) and IoT cybersecurity features.

4. **People and Processes**. The creation, deployment, and use of new technologies begins and ends with people and processes. Many deployments have been hindered – or have failed altogether – when companies do not carefully observe best organizational practices. This includes having centralized and coordinated strategies, based on well-understood business

process and project requirements. In an ideal model, stakeholders are aligned, communication is clear, and projects provide value to the company.

5. **Working with Vendors**. Vendors are a necessary part of the process for deploying Industry 4.0 solutions. The best vendors are partners, helping their clients to succeed. However, challenges exist, including coordinating multiple vendors and their solutions, lack of open interoperability, and need for long-term customer support. To resolve these difficulties companies have turned to key vendors and system integrators, increased their in-house capabilities, looked to open systems and platforms, and collaborated closely with vendors to help develop solutions and ensure long-term customer support.

Roadblock: Networking and the Operating Environment

In order for Industry 4.0 and digitalization to occur, companies require that devices be connected to their networks and to the data centers – regardless of if these data centers are on-premise, in a private cloud, or in the public cloud. A company's operating environment can introduce numerous challenges around propagation and penetration of radio waves, and interference via magnetic frequencies. Additional complexity is added by varying availability of different networks in different geographic areas, as well as the bandwidth and latency requirements of different use cases. Cost is an additional factor – not just the cost of the network itself, but also the cost of the modules in the end devices.

Companies may face unique challenges, depending on their industry. The sections below reflect top challenges facing companies in the energy, manufacturing, and transportation spaces.

Challenge: Lack of Network Availability in the Energy Industry

Energy equipment is commonly located in remote areas that may lack access to traditional networks. Oil and gas wells, wind turbines, solar installations, and coal mining pits may lack access to wired networks or even cellular networks. Companies looking to deploy networks choose a mix of technologies based on what suits them, including fiber optics, microwave, Wi-Max, or private cellular networks such as 5G. In areas without access to fixed or wireless networks, satellite technologies are commonly used.

> "We are in the open-pit mining industry here, not underground. Underground is easy, you just put the optical wire into the hole and you get the signal you need. But it's different if you have an operation in open-pit area… the challenge is the contour of the geographical land or pit."
>
> – Director of a coal mining company in Indonesia

Each use case has different requirements for connectivity, with unique bandwidth, latency, frequency, and power usage needs. The ability for networks to scale, potentially connecting many thousands of devices, is another factor that may commonly be overlooked when evaluating solutions. Companies tend to choose their networking technology based on the use cases, specific logistical details, and the cost of the network and of the modules in the client devices.

Reported Solution: Evaluate Whether to Buy or Build New Networks

Companies looking to deploy Industry 4.0 solutions to unconnected locations must evaluate the cost effectiveness of building their own connections to access core networks or making use of wireless technologies for backhaul. In select areas, fixed wireless may be appropriate for backhaul – either by use of microwave or cellular technologies such as 5G or LTE – while in others, companies must rely on satellite.

Companies have a choice of using multiple networking solutions, including fiber optics, microwave, public or private 4G/5G wireless technology, or satellite. Fiber optics offers the lowest latency and highest bandwidth, but requires fixed locations for end devices and is costly to build. New wireless technologies offer improved bandwidth and latency compared to prior solutions. For use cases requiring large ranges, low bandwidth, intermittent connections, and low power use, Low Power Wide Area Networks (LPWANs) such as NB-IoT and LoRaWAN are suitable.

Companies must also carefully consider the long-term implications of their choice of networking technology. Hardware and software solutions will need to last for many years. In particular, relying on proprietary technology for something as critical as networking is a risk if vendors cease operations. SigFox, a leading LPWAN vendor, is in receivership in France and its US unit has filed for bankruptcy[1]. Smart meters in particular may eventually require a shift to standardized networking, as many energy utilities have deployed proprietary vendor-specific solutions.

Executive Insight: US Energy Utility & Renewable Energy Provider

"There was a huge disconnect when it comes to how data was being recorded, transmitted, and how work orders were performed. All of that was a manual process, it was written down in books and papers… because some of our assets that we acquired over time via mergers and acquisitions were still operating with the mindset of say, 30 or 35 years ago.

[Our digitalization journey] had a lot to do with the philosophy of our organization, the mindset. [We had to] understand the existing processes as to what exactly goes on in such and such business unit, and then once we were able to do that discovery phase for ourselves, we were able to see the areas which needed improvement or the areas which could be digitalized."

- IT Technology Director

[1] https://enterpriseiotinsights.com/20220404/internet-of-things/sigfoxs-american-dream-dies-in-bankruptcy-and-150m-of-debt-as-french-sale-closes

Challenge: Operating Environments in Manufacturing Plants Interfere with Wireless Networks

Manufacturers are increasingly upgrading manufacturing plants and assembly lines from wired broadband connections to Wi-Fi and cellular connectivity. This allows manufacturers to relocate equipment as needed and support the deployment of IoT devices at a much lower cost, as well as supporting the use of handheld and wearables devices for workers, and robotics and machine vision use cases. Autonomous vehicles in particular benefit from 5G's low latency and high bandwidth connections. However, the built environment within manufacturing plants may introduce complications in terms of network reliability and availability, with different building materials hindering or blocking radio-wave penetration and propagation characteristics. Manufacturing processes involving strong magnetic fields may additionally create powerful levels of interference and noise, interrupting network connections and creating areas of poor or no performance.

> "If our operating machines are producing data, I won't use wireless because it's not reliable at all… We do quench and tempering with inductors, thousands of amperes with low voltage that we are using, for heating by magnetic field. And this magnetic field sometimes corrupts data… In some applications where we can accept losing some data, we can also use wireless, and will save a lot of money for connectivity."
>
> – Program launch manager for an auto parts manufacturer in Italy

Reported Solution: Use a Mix of Network Types as Needed

While manufacturing plants are increasingly being upgraded to Wi-Fi and cellular connectivity, select lines and equipment may continue to require wired connections for best performance. To best support the mix of use cases and need for reliability, manufacturers are turning to a mix of networking types – including not just wired broadband but also cellular and Wi-Fi, Bluetooth Low-Energy (BLE) or BLE Mesh, RFID systems, and others. New technologies including adaptive congestion control additionally allow for wireless gateways to better adapt to high-interference environments, supporting better performance in a greater variety of conditions.

Challenge: Orchestrating Devices Across Multiple Networks in the Transportation Industry

The transportation industry is highly diverse in terms of its operating environment and geographic footprint. Unlike other industries, vehicles move across a wide assortment of environments, only some of which are controlled by their owners and operators. Moving vehicles commonly are connected to public networks, including cellular or satellite networks. Vehicles at rest are commonly connected to Wi-Fi networks, which may be owned and operated by the vehicle owners or may be owned and operated by a third party. Airports in particular are a special case, with complicated network ownership structures. Airlines, shipping companies, and services providers seldom own the network to which they connect. Orchestrating devices across this complex arrangement of networks in a safe and secure manner is a challenge.

Reported Solution: Turn to SD-WAN, APNs

Internally, companies are looking to replace MPLS networks with more flexible software-defined wide-area-networking (SD-WAN) technology, reducing their networking costs and creating a network architecture that is more flexible and resilient. SD-WAN additionally allows companies to centrally manage their WAN-traffic policies, easily applying policies across WAN-connected devices. Companies are also increasingly incorporating their own private tunnels to connect to data centers over a telecommunication provider's network. APNs are replacing the use of VPNs, allowing for more secure connections directly over carrier networks as opposed to the open internet. Unlike VPNs, APNs require that carriers be partners in connectivity solutions.

Roadblock: Data Architecture and Infrastructure

In order for the full benefits of Industry 4.0 to be realized, data must be collected and then fed into systems capable of extracting its value and making use of it. The first step is planning data collection. However, data may reside in many different types of systems in a variety of formats, or might not even be available at all. Third-party vendors may have proprietary data formats with data streams that are not generally accessible through APIs. Data silos continue to be a challenge for many companies.

Challenge: Lack of Understanding of Current Critical Processes

In order for Industry 4.0 deployments to be effective, companies first must clearly understand the processes they wish to measure, improve, and automate, as well as the specifics needed to implement these new solutions. Without a clear understanding of current practices and exactly what is needed to implement them using Industry 4.0 technologies, the solutions created may not be capable of performing the functions needed or may cause additional problems down the road. This leads to frustration, wasted development effort, and unnecessary spending.

At the beginning of the Industry 4.0 rollout, many industry decision makers believed that the best practice was for companies to gather as much data as possible and then use AI to determine how best to use it. Today, companies understand that this is a poor practice, and creates an enormous burden on data scientists and developers while also leading to ineffective project development.

> "[There were around] 200 daily alerts… We had to face a lot of claims that the system was not usable because there was too much information, and [staff] only wanted important information. So we had to spend around three, four months to tune it up. We had to determine which information is valid and important, which is not, and what [alert and data] should go to who."
>
> – IT director for passenger transportation company in Poland

> "Tons and tons of information comes in from various data sources. It should come into the common data lake or platform, and then the AI or big data solution should work and give you the right visibility. But unfortunately we haven't really reached anywhere tangible because the amount of work that it requires to put all those business rules together is actually phenomenal. But even after you put those thousands and thousands of business rules together, somehow the output is not the best. Was it the technology or the implementation? I can't comment there."
>
> – VP of operations for a passenger airliner in the UAE

Reported Solution: Carefully Evaluate Project Needs, Including Data, Connectivity, Reliability, and Cybersecurity

Companies must assess what is needed to properly and effectively serve the use case with regards to the specific types of data needed, the connectivity that best supports data collection for the specific location and built environment, the degree of reliability and redundancy required, and how to best build in cybersecurity and data privacy from the onset. As part of this process companies must map processes to understand their components, task ownership, key stakeholders, and timelines. This understanding helps companies to evaluate which processes can be improved or replaced using Industry 4.0 projects, determine who is impacted by resulting change, develop ROI estimates, and create clear expectations and goals.

Challenge: Extracting Value from Data

In order to extract the value from the data collected by Industry 4.0 technologies, it must first be translated into meaningful and actionable insights. Companies that have simply collected available data without first considering potential uses, hypotheses, or how the data will be appropriately formatted and analyzed may encounter difficulty in consuming the raw quantity of data available. Most companies are not equipped to drink directly from the firehose.

Teams of data analysts and data scientists must spend hundreds of hours manipulating and experiment with the data in order to develop AI models capable of digesting data streams and delivering value.

> "The challenge we have is that the system is complex, [which makes it] difficult to read the reports. And when, for example, sending such reports to the executive board, sometimes it's difficult to understand the figures and trends, because the way [the trends] are reported it's quite complex.
>
> – Sub-regional fleet head for airline services in Morocco

Reported Solution: Let Use Cases Drive Industry 4.0 Planning and Deployments

Companies looking to deploy Industry 4.0 projects must carefully plan their deployment of new technologies around their use cases and the company's ability to analyze and act upon the data collected. By deploying according to use cases, companies support proper project planning, allowing for use-case specific best practices to take place, and help to ensure that projects will ultimately be successful and timely.

Additionally, too much data is oftentimes overwhelming for data scientists and analysts, and limiting data to what is necessary and reliable helps to simplify the development of AI models, reduce noise, and improve accuracy.

> "And I think at the heart of it, why that journey has been so painful for a lot of large enterprises is that their process, their tech and their people teams were not aligned to even empower it to be successful. And trying to do too much at once is like pouring the salt on you all at one time - it becomes overwhelming."
>
> "The companies that differentiate themselves are the ones in essence that take little chunks of that problem at a time, figure out what's relevant to them for their business and process needs, and then incrementally implement and succeed and learn from it, and then reiterate and repeat. And a lot of the companies I've dealt with have failed at it because they do the opposite of that."
>
> – Chief Dimensional Officer for US aeronautics company

Challenge: Data Silos Prevent Data Collection and Integration

Data silos continue to be a challenge for companies in any industry. Data, once collected, must be brought into a common platform or database for analysis. Older companies, and companies that grew via acquisitions frequently have multiple systems in place that serve similar functions but do not easily communicate or coordinate with each other. Legacy systems in particular may be difficult or time consuming to integrate.

Integrations in certain circumstances take more time and resources than the Industry 4.0 deployments themselves. Data is also oftentimes collected in formats that are incompatible with each other and collected datasets require cleaning and standardization before analysis can be done

> "A major challenge with our kind of environment is the legacy systems. See, normally metro is a time consuming project and it comes in phases. So I have equipment I purchased 20 years back, I have equipment which I just purchased two years back. So, integration of all those equipment to a system is always a challenge.
>
> – GM of IT for a metro rail company in India

Reported Solution: Cloudification, Normalization of Data, Make Use of APIs for Communication Between Systems

Many companies are either currently making use of the cloud or in the process of moving to the cloud. Cloud-based systems are helping to unify business approaches and plans across different geographies, enabling centralized strategies and greater economies of scale with regards to Industry 4.0 deployments, while also simplifying integration and centralization of data.

Data normalization is a key step in automating integration between the cloud and various systems, including Industry 4.0 technologies. Additionally, an increasing number of vendors and platforms are offering public and private Application Programming Interfaces (APIs) that allow for easier automatic communication and translation between systems and applications.

> "As a platform, I've currently got a development product roadmap around integration. So I have a number of integration points which we build based upon different methods of bringing in the information."
>
> "I'm trying to standardize on a set of APIs, which will then allow [our] third party customers with their own units to be able to hook into providing us with data, while also retrieving the analytics information."
>
> – IT Director for a trailer sales and leasing firm in the UK

Roadblock: Cybersecurity and Cyber Threats

Cybersecurity is a major concern among companies in every industry. Many companies and key decision-makers report having uncertainty around mission-critical technology being connected to the internet, with particular concerns over using publicly shared hardware. Those in the energy and transportation verticals are especially concerned, given the sensitivity of the data they handle and the fact that they are part of a nation's critical infrastructure.

> "Our structure works by simply connecting all the machines in a segregated network, segregated from the outside because you can imagine what would happen if some internet connection would be available inside a plant, the machine can get a virus or a hacker creating damage…"
>
> "I know, personally, companies that lost data because they had a computer or machine with Windows XP, they have got, they don't know how, a virus, and a hacker… they locked, encrypted everything, and asked for money to unlock the data. [The company] got stuck for a month, it was terrible."
>
> "We are connected, we work with data, and data needs to be protected."
>
> – Program launch manager for automotive manufacturer in Italy

Although historically some companies might have deemphasized robust security measures for cost savings, with digital transformation these risks can no longer be overlooked. Cyber-threats and cyberattacks against companies are growing worse, and the attack surface is only increasing as advancements in operational technology means that more systems are connected to the internet. Companies are increasingly turning to private networks, segregated and segmented networks, and zero trust models. However, many existing cybersecurity solutions focus on the security challenges facing IT, leaving a gap in the market for OT (operational technology) security.

These concerns around cybersecurity are additionally delaying companies' moves to public cloud, particularly companies that handle sensitive data. Governments across the world oftentimes have regulations that restrict where data is able to be geographically hosted, as well as who can access it. It has become common for companies dealing with transportation or critical infrastructure to host data locally inside the country of origin's geographic borders. For select industries and vendors – including nuclear power plants and manufacturers contracting with the US Department of Defense – data may need to be hosted on-premise and networks air-gapped in order to fully comply with regulations and requirements.

Challenge: Public Cloud Connections May Be Insecure

Public cloud connections may offer many operational and cost advantages for companies looking to digitalize and deploy Industry 4.0 solutions. By using these solutions, companies no longer need to own their own hardware, are not responsible for managing infrastructure, and may have lower latency for applications taking place in different countries and regions. However, the use of the public cloud does introduce security concerns, including cyber threats designed to target cloud

services. Privacy and data security may additionally be a concern, with geographic data sovereignty a key factor for any business handling sensitive data or critical infrastructure.

Many companies make use of Infrastructure as a Service (IaaS) offerings, partnering with Amazon Web Services, Microsoft Azure, Google Cloud, or others to host workloads and ensure redundancy and high performance. Maintaining a consistent cybersecurity approach across these multiple platforms has proven to be a key challenge to teams.

Reported Solution: Consider Hybrid Public/Private Cloud Models

Using a mix of public and private cloud or on-site data centers may offer a beneficial middle ground to businesses. Non-critical workflows and processes handling non-sensitive data are less likely to cause issues if cyber threats materialize, and can be more safely hosted in the public cloud. Private cloud deployments may be used for data and processes requiring higher levels of security. Private cloud is a good fit for sensitive data and regulated workflows, such as the data handled by companies in the transportation and energy industries. New hybrid cloud solutions integrate public and private cloud and on-premise infrastructure in an easy-to-orchestrate way, simplifying management for staff and easing burdens on IT teams.

> "If possible, we use the cloud… But in nuclear power, we are very concerned about cybersecurity, so you cannot connect to the cloud from the reactor building or power plant… we develop our own internet software, it's usually on an on-premise server, rather than a cloud server. If the data is related to nuclear it is on the on-premise system, and if not it's on the cloud-based system."
>
> – Digital innovation manager for nuclear & wind energy company in the UK

Challenge: Insecure Operational Technology

Companies may not be able to modernize the entirety of their legacy networks and operational technology. Equipment may exist in the field or on the floor for many years, potentially decades, without any ability to upgrade firmware – even as zero-day threats are discovered and made public. However, in order for Industry 4.0 solutions to function, they may require an internet connection to a vendor's cloud or otherwise be exposed to the internet.

This creates an entirely new threat vector for cyberattacks. Many solutions for network monitoring and cybersecurity on the market today were created for IT frameworks and solutions, not the complex world of operational technologies.

> "In Industry 4.0 we have issues because most of our networked components use proprietary protocols, which is an issue to our scanning tools. So we have to create some smaller networks and create some kind of very creative firewall tricks to protect our infrastructure…"
>
> "We can't cut, pull the plug for those components, create a separate network, completely isolate the component, because it won't work at all. So the only way is to give access but monitor."
>
> – Head of enterprise architecture at an energy producer & utility in Brazil

Reported Solution: Make Use of Best Practices when Designing Networks

Companies looking to deploy Industry 4.0 solutions must be careful to observe best practices when designing their network infrastructure, making use of software-defined networking principles where available. Companies can segregate their network traffic, protecting and monitoring potentially insecure IoT devices.

New approaches to cybersecurity, including zero trust models, assume that threats may materialize at multiple parts within the IT and OT infrastructure – including within the network itself. Especially critical systems may need to operate independently, without any internet connections or a connection only to a local data center. A growing class of cybersecurity solutions are arising to tackle the challenge of the billions of Internet of Things devices coming online across industries. These solutions carefully monitor devices' internet traffic and behavior, detecting when they are out of bounds with past behavior and sending an alert. Devices are able to be individually identified and quarantined if necessary.

Challenge: Legacy Networks Are Insecure

Legacy network infrastructure may have multiple points of insecurities that leave companies open to intrusion and cyber-attacks. Components were designed for a much simpler and less risky network operating environment, and cybersecurity is oftentimes an afterthought or completely overlooked. Networks may lack modern features allowing for in-depth monitoring of network traffic, and tools such as software-defined networking. Continuing to use these networks presents an on-going risk to companies.

Solution: Modernize and Standardize Legacy Infrastructure when Possible

Modernization of legacy networking infrastructure allows for the deployment of new cybersecurity measures, enabling businesses to better protect critical business operations against ransomware attacks and other disruptions. Companies must be prepared to carefully plan downtimes for the upgrades or even replacements of crucial systems and components.

Few companies will be able to do this all at once, instead upgrades and replacements may need to be staggered in order to keep costs manageable and operations on track. Companies have found that in addition to improving cybersecurity, this modernization helps to improve operational efficiency and may directly boost ROI.

> "We are trying to standardize our network infrastructure. We are modernizing legacy components. It's hard to do because we are talking about crucial components, so we have to plan downtimes. It's hard to do."
>
> "In a sense, we are trying to modernize this company to bring more security as the main [goal]. We are trying to search for more efficiency, but one main driver for us is security of our operations. Energy is a strategic field, it's critical to our business."
>
> – Head of enterprise architecture at an energy producer & utility in Brazil

Roadblock: People and Processes

Many of the top challenges that companies face with regards to their Industry 4.0 rollouts are not necessarily about the technology itself, but rather about the people and processes involved. Executives across industries emphasize that challenges begin with planning and strategizing, ensuring that stakeholders are aligned and on board with strategies, and that processes and project requirements are clearly understood. Change management, clear expectations, and clear communication are essential at all levels of business.

Challenge: Fragmented Approaches to Deployment

Companies looking to deploy Industry 4.0 solutions need to begin somewhere. Commonly, ideas for new solutions types begin on the floor or in the field, among the staff and personnel directly engaged with the work. Supporting these ideas, working with local teams to develop solutions that fit their needs allows companies to innovate quickly. However, this practice becomes problematic when multiple locations are separately implementing similar but slightly different solutions. This practice is costly, both in terms of redundant development work and in terms of maintenance needs. Fragmentation also may hinder development of new Industry 4.0 solutions, as each separate solution will have their own integration requirements.

Reported Solution: Centralize Strategies with an Organization-Wide View

Best practices for planning solutions include top-level support and a centralized strategy, but with input and feedback from local teams. Identify leaders within the company that will grow internal expertise and establish teams for the purpose of evaluating solutions and driving organizational change. Have a change management process in place to help ease employees' and teams' resistance to change, improve familiarity with digital technology and its uses, and ensure that employees and teams do not see new technology as a threat.

> We want to make deployments companywide, because we have to maintain these kinds of technology solutions [going forward]. It's difficult if you have different solutions in the different plants and companies and countries, we want to have standard solutions all through the company… we try to make the solutions as easy to maintain as we can."
>
> – CTO for a steel manufacturer in Argentina

Challenge: Managing Expectations and Bringing Stakeholders on Board

There are many uncertainties around the impact Industry 4.0 solutions will have, not just on the company at large but also on the daily tasks of teams and of individuals. Managing expectations for all levels, from the C-Suite on down, helps to eliminate uncertainty and align stakeholders.

Companies may experience issues where key personnel have reservations or do not see the benefit of these uses of technology compared to the current way of doing things. This may include personnel who do not officially have relevant job titles, but otherwise occupy unofficial roles and are recognized as leaders.

Reported Solution: Prioritize Change Management, Training for Staff at All Levels

Implementing new technology is not just about technology itself, but also a matter of processes and people. The rollout of Industry 4.0 solutions may require many levels of cooperation within a company; developing a structured approach to change following the principles of change management and working with leaders at different levels of the company help to bring staff on-board.

> "One [roadblock] is the curmudgeon effect, you know, which is people that just don't see why you would change anything. You've always run into people like that. That's why we [first worked with] the plant managers that were more open-minded. Then as they made [Industry 4.0] work, everyone saw the positive advantage.
>
> – CIO for an auto parts manufacturer in USA

Challenge: Communicating Project Value and Estimating ROI

Quantifying ROI for new and innovative deployments may be challenging for companies. Not all resulting benefits will be easily provable or understood by key stakeholders, and value delivered may not strictly be monetary. Projects may include high CAPEX and OPEX investments, as well as require varying degrees of organizational change – a concern for many businesses, given uncertain ROI.

Companies looking to deploy Industry 4.0 projects must determine the value of projects and evaluate ROI to the best of their ability before rolling out large-scale deployments. However, launching pilot projects gives companies the opportunity to better understand the impact and requirements of new innovations without requiring large up-front investments.

> "The challenge that sometimes we face is that we are talking about innovations. I give you an example where we talk about running out an autonomous vehicle, how do you prove it, it's new. What is my ROI? There's no way I can prove, because whatever I tell you is really plucking the numbers from air, because it's so new."
>
> – VP of digital transformation for passenger transport in Singapore

Reported Solution: Conduct Small-Scale Pilot Projects to Evaluate Solutions and Estimate ROI

As Industry 4.0 projects are complex and largely unique, even the best project planning may not be able to determine fully what is needed and how to best approach deploying the technology. By running small scale pilots, companies can gain insight into best practices for deploying individual technologies and projects, gain valuable data on return-on-investment, and more closely understand deployment needs and timelines.

Roadblock: Working with Vendors

For Industry 4.0 deployments, multiple vendors are sometimes needed to provide the technology, equipment, or software, install it, and maintain it. Coordinating deployments with these various vendors may add considerable extra time to deployment schedules, particularly with regards to designing ecosystem contributions and integrating back into core systems. Integrating with existing legacy technology adds an additional layer of complication.

Customer support, especially long-term customer support, as well as communication and delineation of responsibilities and goals may also challenge companies. Companies may have projects with lifecycles spanning many years – sometimes decades – and require long-term support and guarantees that hardware and software continue to be supported.

Challenge: Coordinating Multiple Vendors

Coordinating the activities of multiple vendors is a challenge for many companies, given the complexities of managing each individual part of a project. Communication errors and breakdowns, integration challenges, and incompatible timelines may all introduce difficulties to companies looking to deploy Industry 4.0 projects.

> "Integration is especially a big issue if there are many companies coming together for one solution."
>
> – Chief of intelligent engineering, for an auto manufacturer, China

Reported Solution: Build In-House Coordination Capabilities or Partner with a System Integrator or Vendor Capable of Coordinating For You

Companies that have found the greatest degree of success in Industry 4.0 deployments are those that have grown their in-house capabilities to coordinate ecosystem contributions and build their own integrations. These companies have a deep understanding of what is needed to do Industry 4.0 well, and are able to leverage this understanding into their relationships with vendors.

Companies that are just beginning their Industry 4.0 journeys would do well to hire team members with this technical and logistical expertise, and invest resources into training existing staff. However, given the potential degree of complexities involved with deployments, and the rapid advancement of technologies, it may not be possible for companies to internally coordinate all projects.

Reported Solution: Partner with a System Integrator or Vendor Capable of Coordinating For You

Many companies must determine which projects can be coordinated internally, and which projects must be left to an expert vendor or team of vendors. System integrators specialize in coordinating vendors and integrating products and solutions, providing implementation advice to companies and recommending specific networking structures, vendors, and solutions. Tier one vendors commonly offer in-house system integrator capabilities, bringing on other vendors as sub-contractors. This

process may be more expensive than internally coordinating projects and ecosystem contributions, but is more scalable and introduces less room for error for major undertakings.

Challenge: Proprietary Protocols & Lack of Open Systems & Interoperability

Many aspects of the networking and IT world have embraced open platforms and open interoperability. Open approaches to hardware and software have driven major innovations in the cloud and data center world, later making their way into network infrastructure. This has enabled innovations like software-defined networking, allowing companies to more easily integrate solutions from multiple vendors and avoid vendor lock-in.

Support for openness in operational technology is lagging in these sectors, increasing the difficulty involved in piecing together solutions and requiring greater levels of effort by vendors and companies for collaboration.

> "Finding vendor-agnostic technology is hard to do in this space… the vendor has locked them down or considers them to have some kind of IP… it can be difficult to piece everything together… [the vendor] wants you to buy their whole entire stack to actually get the process or data. And that's one of the biggest roadblocks: open source, open interoperability is not easy to achieve."
>
> – IT capability architect in oil and gas, USA

Reported Solution: Look for Open Platforms and Solutions

Companies must evaluate Industry 4.0 solutions to determine if they follow standardized protocols, and if APIs allowing open data exchange are available. This more easily allows companies and system integrators to incorporate solutions into companies' overall platforms and ecosystems. Companies should also look for vendors with wide ecosystems of partners, or those that embrace vendor agnostic platforms and solutions in their approach.

> "[Data silos] have been an issue always. However, now companies are getting into an approach of open data systems, either through the API connectivity between various systems, or they are utilizing technologies that already have connectors to the various systems they're using. Or the manufacturer has the connection to the centralized system that corporate is trying to implement."
>
> – Executive manager in oil and gas, UAE

Challenge: Differing Roadmaps and Long-Term Support

Companies may require carefully tailored solutions that best meet their requirements. However, these solutions do not always match what is on vendors' roadmaps. Smaller vendors may be more agile and able to meet individual needs. But companies may require long-term support from the solution vendor, which may be endangered if that vendor is acquired or fails.

Reported Solution: Collaborate Closely with Vendors to Develop Solutions and Ensure Long-Term Customer Support.

Companies are collaborating closely with vendors to co-create new solutions, moving towards more of a partnership model. Close collaboration helps to ensure that solutions are a best fit for companies. Long-established vendors can bring a measure of stability to post deployment relationships. Some companies though, working with smaller vendors and start-ups, take the extra step to invest in them to help ensure their long-term survival.

> "We are co-creating with the vendor themselves because we are moving into areas which were not transversed earlier by the company. So there are no ready-made solutions being offered by vendors. But we are very sure what our requirements are."
>
> – Director for an energy utility, India

Conclusion and Top Considerations

Companies see a multitude of benefits through undergoing digitalization and deploying Industry 4.0 solutions. These benefits span from operational improvements, increased efficiency, increased visibility, improved safety, to many others. While many use cases for Industry 4.0 technologies are specific to a company's exact business and business practice, a number do apply across industries. Companies looking to deploy Industry 4.0 solutions must consider the following:

Top Considerations for Overcoming Roadblocks

1. **Create a Five to Ten Year Digitalization Roadmap**. Companies interested in deploying Industry 4.0 technologies must centralize their strategies and create long-term roadmaps around their use of technologies. This includes putting together internal leadership, dedicated teams, and ensuring organizational support for necessary initiatives.

2. **Make Targeted Investments for Digitalization and Industry 4.0**. Companies will all be at different places with regards to their equipment and assets, network infrastructures, use of the cloud or on-premise datacenters, data architecture capabilities, relationships with vendors, and the skills and capabilities of in-house teams. Current capabilities and assets may need to be upgraded or replaced in order to support new technological initiatives. This does not need to happen all at once, but may be staggered as needed to support individual rollouts.

3. **Follow Best Practices for Project Planning**. Before deploying Industry 4.0 solutions, companies must carefully determine their use cases and what is needed to achieve these use cases. This may include the deployment of specific types of sensors that capture data; new networking technologies that support the bandwidth, latency, reliability, and scalability needed; or new cloud or hybrid platforms. Companies must be careful to determine what data and data types are needed as well as how the data is to be formatted and delivered into their systems. Before committing to a full-scale deployment of new technology, companies will be best served by launching smaller pilot projects and iterating based on learnings.

4. **Build in Cybersecurity from the Onset**. Before committing to deploying a specific technology, or even building the core foundation, companies must carefully consider their cybersecurity strategy and best practices. Cyber-threats are growing, and with operational technologies increasingly connected to the internet attack surfaces for companies are widening. It is much easier for a company to design and add cybersecurity measures during the initial states of project planning than as an afterthought.

Appendix

Methodology

Parks Associates analysts conducted thirty in-depth interviews with executives between December 2021 and March 2022. Interviewees were engaged in the operations of their companies, and familiar with the roadblocks to implementing Industry 4.0 strategies. Interviews lasted between 45 and 90 minutes each.

Executives interviewed represented companies across energy, manufacturing, mining, and transportation sectors.

- Energy Industry: 11 executives interviewed in companies in the following sectors: Electrical Grid, Wind Generation, Solar Energy, Biogas, Coal Mining, Nuclear, Oil and Gas, Natural Gas
- Manufacturing: 10 executives interviewed in companies in the following sectors: Aircraft Manufacturing, Appliance Manufacturing, Automobile Manufacturing, Component Manufacturing, Steel Manufacturing, Metal Mining
- Transportation & Shipping: 9 executives interviewed in companies in the following sectors: Airline Services, Cargo Airline, Metro Bus System, Metro Rail, Passenger Airliner, Passenger Transport, Trailer Sales and Leasing