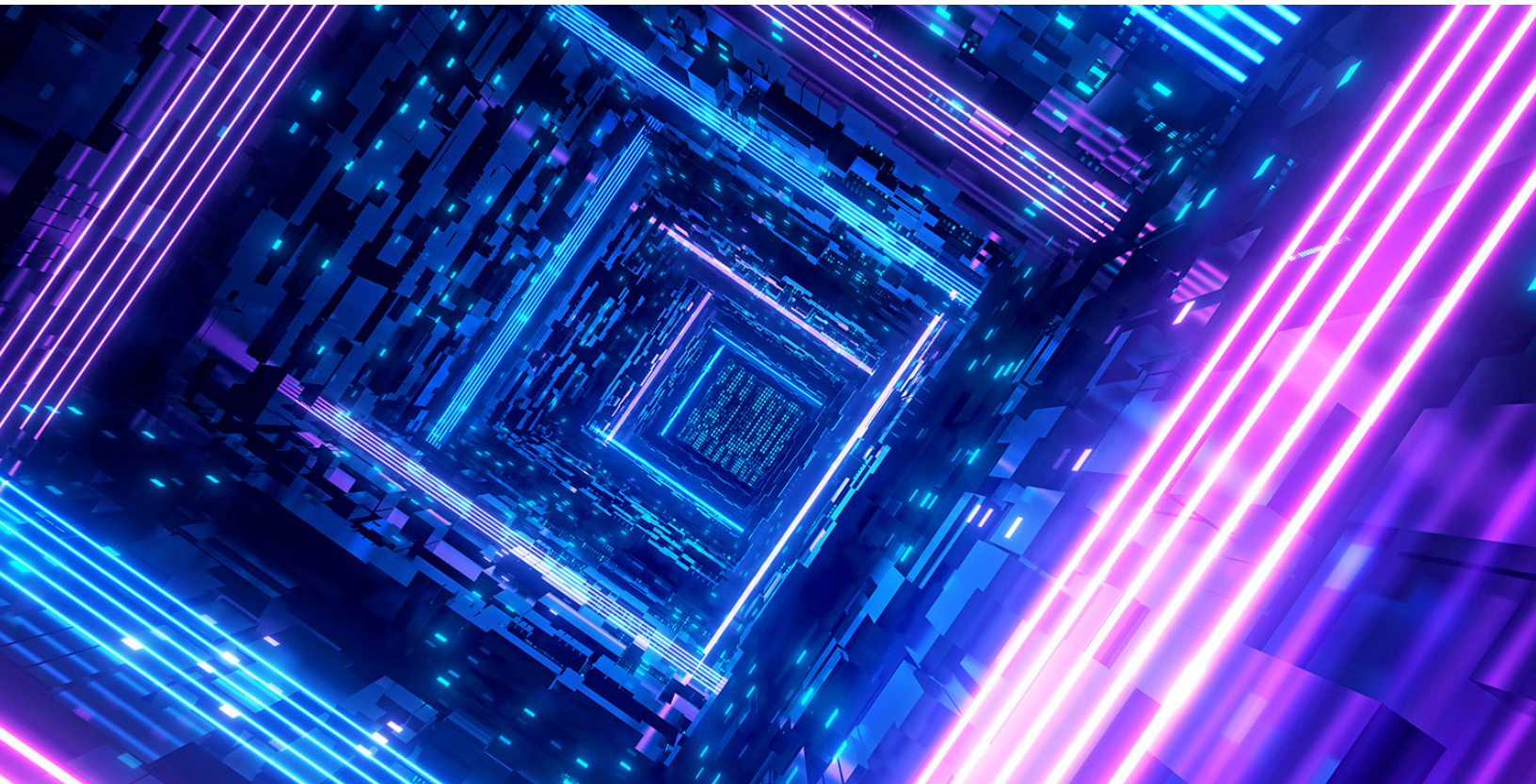


Operations Practice

Adopting AI at speed and scale: The 4IR push to stay competitive

AI has brought the Fourth Industrial Revolution to an inflection point, and manufacturers must choose a path forward: innovate, accelerate, or follow fast.

by Henry Bristol, Enno de Boer, Dinu de Kroon, Forest Hou, Rahul Shahani, and Federico Torti



The world has changed for manufacturers.

Preparation for uncertainty has become an industry norm, with executives expecting the impact of disruption—whether from geopolitical tensions, climate change effects, technology breakthroughs, or supply chain vulnerabilities—to increase by 15 to 25 percent over the next five years.¹

At the same time, advanced manufacturing is now flourishing in markets where stagnation had seemed intractable. Growth in the US manufacturing sector, for example, had languished at 1.4 percent over the past two decades. More recently, AI, digital technologies, sustainable features, and higher skill have reinvigorated the market: over the past five years, US industrials companies have generated total shareholder returns about 400 basis points higher than in the previous 15 years.

The accelerating pace of the Fourth Industrial Revolution (4IR) can help enable this type of next-level performance while also increasing workforce inclusivity and sustainability. The Global Lighthouse Network,² now in its fifth year, provides an expanding pool of examples. In effect, each Lighthouse cohort provides a three- to five-year look ahead at the future of operations across the value chain.

The most recent cohort affirms a 4IR inflection point, marked by two factors. First, machine intelligence technologies—AI that, rather than seeking to simulate human intelligence, empowers machines with the specialized intelligence needed to perform complex tasks in the cyber-physical world of production—are reaching unprecedented levels of maturity. Second, leading companies are redefining the concept of a pilot as they scale impact by using entire factories, rather than individual use cases, as pilots.

This series of three articles will explore: (1) the current status of global manufacturing, with a particular focus on (2) what AI looks like among today's leading manufacturers, and (3) the

capabilities they have built to deploy it with both speed and scale. In this first installment, we'll explore how the maturity of AI marks a 4IR inflection point; examine how leading manufacturers are redefining the leading edge of manufacturing with this technology; and finally, consider three types of strategic responses—to innovate, to accelerate, or to follow fast—that manufacturers will need to consider as industry becomes more competitive. The second and third articles, respectively, will focus on the at-scale impact of AI within the manufacturing sector and the essential capabilities that drive AI adoption.

The S-curves of industrial revolution

Global industry transformation has never been instantaneous. Each “revolutionary shift” saw a lag period between the introduction of the enabling foundation and widespread adoption. Consider the steam engine. The Roman architect Vitruvius made mention of a rudimentary steam-powered device as early as 15 BC. Why, therefore, did widespread adoption take more than 1,800 years? The answer is simple: steam was neither practical nor cost-effective until breakthrough engine technologies—along with the infrastructure of coal supply chains—made it so. This tipping point essentially eliminated the learning curve, allowing the “doing curve” to steepen. The front-runners had done the learning. It wasn't until the late 18th century that, in the space of just 20 years, steam engine adoption in industry increased from practically nothing to nearly 80 percent.

What steam was to the First Industrial Revolution is what AI will be to the fourth. And much as coal supply chains and factory infrastructure were the tipping point that enabled steam power to race up the adoption curve, data collection and data infrastructure are doing the same in the fourth. Already, some of the world's leading factories generate multiple petabytes of data a week. If all ten million factories in the world operated at this level, they would double all human information in

¹ “The great acceleration: CIO perspectives on generative AI,” MIT Technology Review, July 18, 2023.

² The Global Lighthouse Network is a World Economic Forum initiative cofounded with McKinsey and counseled by an advisory board of industry leaders, including Contemporary Amperex Technology, Foxconn Industrial Internet, Henkel, Johnson & Johnson, Koc Holdings, Siemens, and Schneider Electric. Lighthouses in the network are designated by an independent panel of experts.

less than a month (see sidebar “The evolution of the revolutions”).

The adoption S-curve

We can see a pattern as we look back upon each industrial revolution: it has always taken the shape of an “S-curve.” The first phase is a learning curve, which tends to be long, and is marked by trial and error as early front-runners figure out how to make things work. It then moves on to the next phase, the “doing” part of the curve. This is when the foundational technology has been established, and organizations work to deploy it across their production networks. Finally, we see an optimization curve, which is when industries align around what works best. New standards and protocols become ingrained, and costs start to stabilize (Exhibit 1). One need only look back at a now-ubiquitous technology, such as the smartphone, to recognize this three-phase S-curve in play.

One of the most significant differentiators for members of the Global Lighthouse Network—the 153 factories at the forefront of the Fourth Industrial

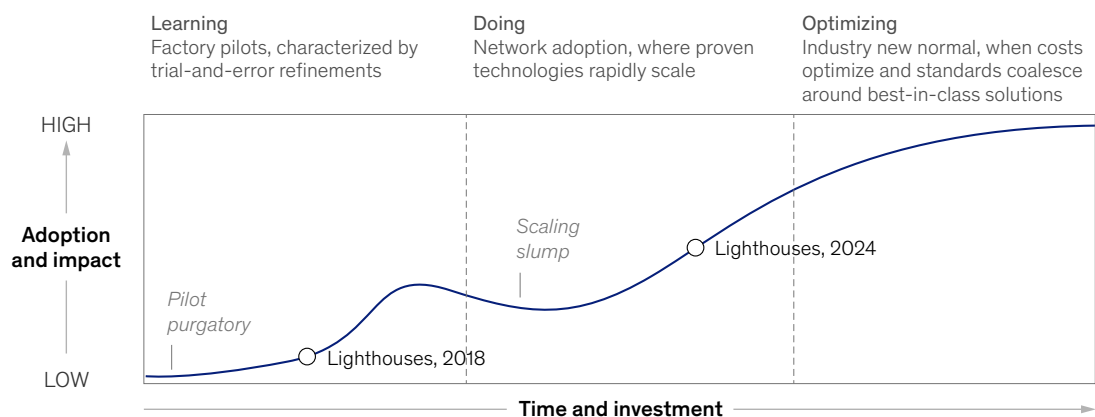
Revolution—is that we believe them to be three to five years further along 4IR’s adoption curve than are other manufacturers. Today, they aren’t focused on piloting use cases. Instead, they’ve built the capabilities to get new use cases right quickly and without trials. For companies with multiple Lighthouses, *entire factories* serve as pilots for networkwide deployment at scale. Leaders are now capturing the value of 4IR technologies ten and 50 factories at a time, where others are still working to find value within a single factory.

Lighthouses are accelerating, and so too is the maturity chasm they have put between themselves and everyone else. This chasm is evident in the wake of recent disruption and volatility. Consider that 85 percent of Lighthouses saw revenue reductions of less than 10 percent during the height of the COVID-19 pandemic; this was true for only 14 percent of other manufacturers. Lighthouses could react quicker: although they faced the same supply chain risks, 65 percent of Lighthouses were already dual-sourcing and increasing inventory by 2022, compared with only 24 percent of other companies.

Exhibit 1

From learning to doing: Lighthouses are rapidly climbing the Fourth Industrial Revolution adoption curve.

Fourth Industrial Revolution (4IR) adoption curve, illustrative



Source: *Global Lighthouse Network: Adopting AI at speed and scale*, World Economic Forum, December 2023

AI is defining the Fourth Industrial Revolution

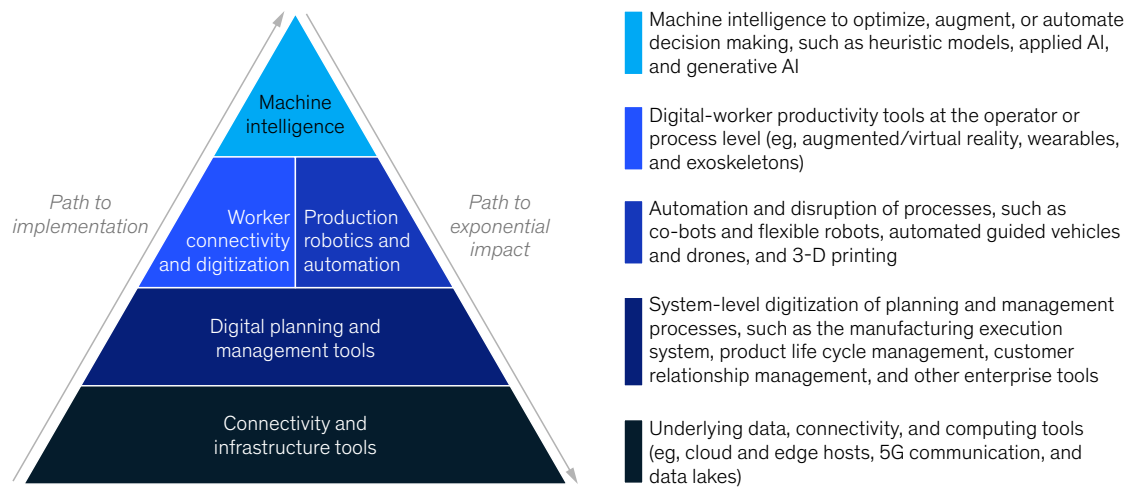
The true power of AI for the Fourth Industrial Revolution lies with the fact that it sits at the top of a

“pyramid” of 4IR technologies—it is playing the role of conductor for 4IR technologies, which together perform a symphony of impact (Exhibit 2).

Exhibit 2

The full value of Fourth Industrial Revolution technologies comes from a suite of technology solutions.

Fourth Industrial Revolution (4IR) technology pyramid



McKinsey & Company

The evolution of the revolutions

Late 18th century

- Revolutionary shift: steam power and mass production techniques
- Unlock: mechanization
- Enabling infrastructure: coal supply chain

Late 19th century

- Revolutionary shift: electrification, assembly line production, new resources, and synthetic materials

- Unlock: mass production

- Enabling infrastructure: electrical grid

Mid-20th century

- Revolutionary shift: programmable logic and control loops for automation of robotics and reduction in manual tasks

- Unlock: standardization and automation

- Enabling infrastructure: semiconductors and transistors

Today

- Revolutionary shift: machine intelligence to make trade-off decisions enabling augmentation and optimization

- Unlock: advanced manufacturing
- Enabling infrastructure: big data

AI is defining the Fourth Industrial Revolution, and Lighthouses are showing us that AI has myriad new use cases and possibilities for unimaginable performance improvements.

Consider the example of a rapid changeover at a production site (Exhibit 3). This requires flexible robotics to handle different products, automated guided vehicles to move materials and parts, 3-D printing to customize line fixtures, and wearable technology to keep managers and technicians informed with real-time data. What orchestrates this complex interplay of elements, each of which is individually complex? The answer: AI.

But AI needs terabytes of data generated by and collected from a broad range of sources: enterprise systems, machine sensors, connectivity infrastructure, and human workers. That's why the most advanced front-runners are ahead. They had the foresight to make investments and take on risks involved in building the data foundations that are needed to power AI technologies and unlock their potential impact (see sidebar "Understanding AI: How it actually works).

With AI, machine intelligence can orchestrate highly complex technologies for rapid solutions.

Capabilities to tackle the scaling slump

AI is defining the Fourth Industrial Revolution, and Lighthouses are showing us that AI has myriad new use cases and possibilities for unimaginable performance improvements.

Use cases inform capabilities, and capabilities lead scale. Back in 2018, cutting-edge use cases looked like localized applications of advanced analytics and autonomous vehicles, or radically

transparent data connectivity and visualization dashboards, and similar digital-lean solutions. These use cases took much longer for Lighthouses to implement than they do today; where most Lighthouses say it took ten to 20 months average time to implement their first five use cases, 75 percent say they can now do it in less than six months. Even more impressively, 30 percent claim they can do it in less than three months.

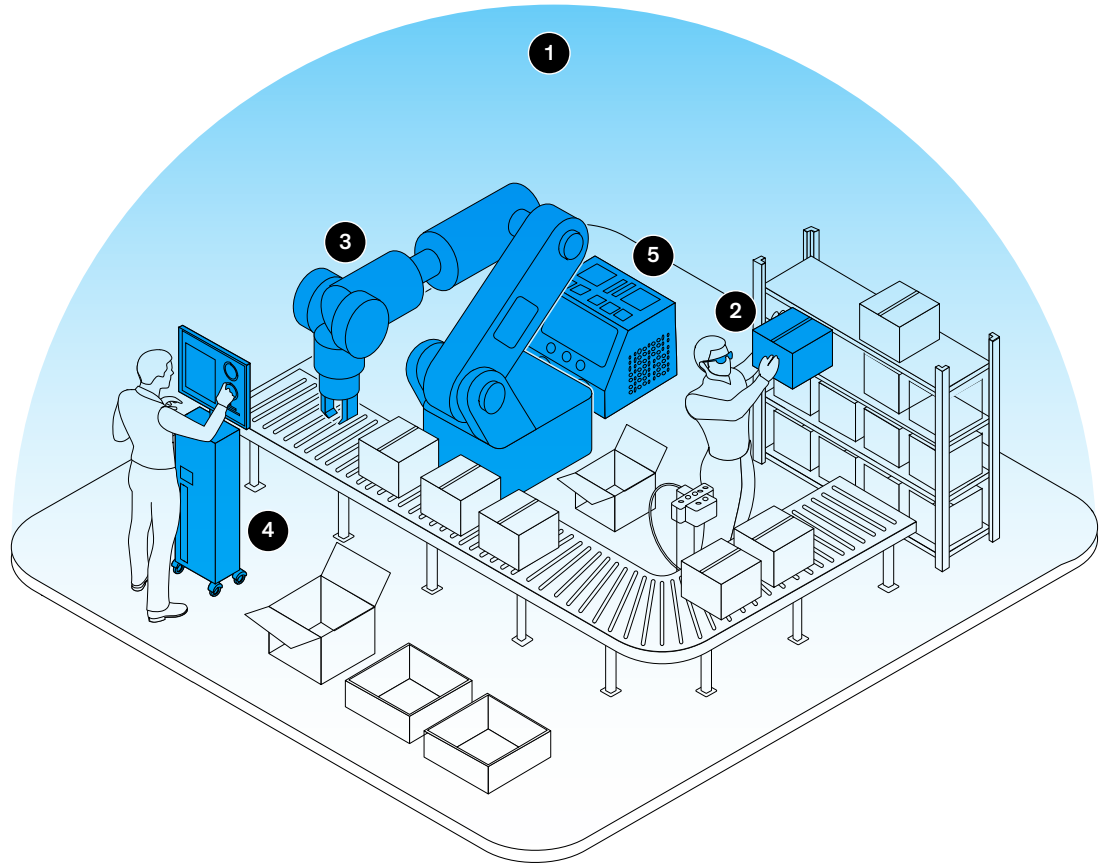
This is because for early use cases, factories first had to rewire their data collection and connectivity layers, design tech stacks that added to or upgraded legacy infrastructure, train their people on how to use advanced new tools, and reorganize themselves to deploy digital solutions quickly and with strong feedback. Once built, these capabilities became the foundation for the rapid deployment of new use cases. One Lighthouse, for example, says it was able to implement a gen-AI-based technician adviser in just days and weeks, not months and years.

Ongoing challenges see Lighthouses move from pilot purgatory to scaling slump. At the factory level, capabilities are a solved problem, at least for Lighthouses. Now, many Lighthouses are in the valley that follows the "false peak" of the learning curve, stalling on impact while they rewire themselves for network scale. This isn't easy. Taking a technology that works in one place and extending it across an entire production network introduces massive new challenges: data, technology, talent, and organizational challenges that exist at a single site are not the same at the macro level—and neither

Exhibit 3

With AI, machine intelligence can orchestrate highly complex technologies for rapid solutions.

Implementation of a “one click” changeover



- 1** **Machine intelligence** “conducts” an orchestra of Fourth Industrial Revolution technologies, maintaining system, timing, sequencing, and responsiveness
- 2** **Wearables and devices** give critical alerts to technicians based on real-time data
- 3** **Flexible robotics** are designed to be easily reprogrammed so they can handle multiple, diverse products
- 4** **Integrated systems**, including the manufacturing execution system and distributed control system, inform and control all machines needed to make the next product
- 5** **Cloud and edge hosts** connect all systems wirelessly and execute critical computations

McKinsey & Company

are the solutions. For that gen-AI-based technician adviser to see the light of two dozen factories, those factories must first be ready to receive it.

Those that overcome the scaling slump can define entire industries. This is because they set standards. The adoption of steam engines in manufacturing is an early example. For a more modern-day example: consider Toyota, which managed to scale its production system at the macro level. Shortly after, lean manufacturing and Six Sigma became standard fare for companies all across the world—with the accompanying emergence of new standards, protocols, certifications, and regulatory measures. The innovations became institutionalized; Toyota defined the new normal, which is reflective of the optimization phase of the adoption curve. In other sectors outside of manufacturing, such as tech and banking, AI is already at this stage, so the conversations are focused on standards and regulatory compliance. These sectors can deploy AI at scale, fast—for example, Microsoft was able

to integrate ChatGPT into Bing mere months after its launch.

And like both the steam engine in the First Industrial Revolution and AI technologies in tech and banking, we expect 4IR's breakthrough technologies to catapult from single digit to widespread adoption within the decade. Lighthouses are leading the way. Already, AI-based use cases make up over 60 percent of the use cases presented by new Lighthouse applicants, up from just 11 percent in 2019.

Lighthouses are accelerating the leading edge: How will you respond?

Although it may be some time before gen AI and other highly advanced emerging technologies see networkwide adoption in manufacturing, Lighthouses are already achieving factory-scale adoption. All of the newly recognized Lighthouses have at least one gen AI pilot in process, and several have implemented, tested, and iterated

Understanding AI: How it actually works

Before exploring in detail how Lighthouses have been rapidly adopting analytic AI and piloting its emergent offshoot, generative AI, it's first crucial to gather a basic understanding of what underpins AI. Everyone is talking about it, which raises a worthy question: Do you actually know the fundamentals of how AI works?

Pioneered in the 1950s, AI now refers to the broad field of developing machines, applications, and tools that approximate human behavior, including all aspects of perceiving, reasoning, learning, and problem solving. The first instances included statistical analyses and predictions enabled by early computers.

A subset field in AI, *machine learning*, began developing traction by the 1980s. It focused on teaching machines to learn relationships hidden in data and to build approximate models of real systems. Within two decades, a branch of machine learning called *deep learning* emerged, as "neural networks" became popular methods to model real systems by mimicking how the human brain works, with millions of computational "neurons." 2017 saw the popularization of transformers and the advent of *generative adversarial networks*, a type of deep learning known as *generative AI (gen AI)*, which has enabled use of exceptionally large neural nets called

large language models (with hundreds of billions of neurons) that can learn especially abstract patterns (exhibit).

Each of these breakthroughs has followed its own accelerating adoption curve. Today, both machine learning and deep learning techniques, excluding generative adversarial networks (gen AI) and encompassing such methods as gradient and adaptive boosting, random forests, convolutional and recurrent neural networks, decision trees, support vector machine algorithms, and more are collectively referred to as *analytic AI*. This family of technologies has seen rapid maturity and pace of adoption by Lighthouses.

Understanding AI: How it actually works (continued)

The next evolution: Gen AI

Gen AI is projected to add between \$2.6 trillion and \$4.4 trillion in annual value to the global economy¹—nearly a quarter of which could be captured by productivity improvements of up to two times and task automations of nearly 70 percent across activities related to manufacturing and supply chains.² That’s why it makes sense that, as of mid-2023, nearly one-third of all companies surveyed said that they have implemented gen AI in at least one business function.

Gen AI’s differentiating factor is that it can pay attention to patterns across immense

unstructured data sets, like a human brain. It leverages a “transformer” architecture to generate “embeddings”—an approach initially designed for natural language processing tasks. Embeddings are massive vectors representing hundreds of thousands of parameters for any given “token,” or piece of information. (For text-based models, a token might be as small as the prefix “un.”) It can predict or “generate” content by identifying a probability that any one token will sequentially follow another token. This probability calculation accounts for the proximity of that token’s vector embedding with others stored in

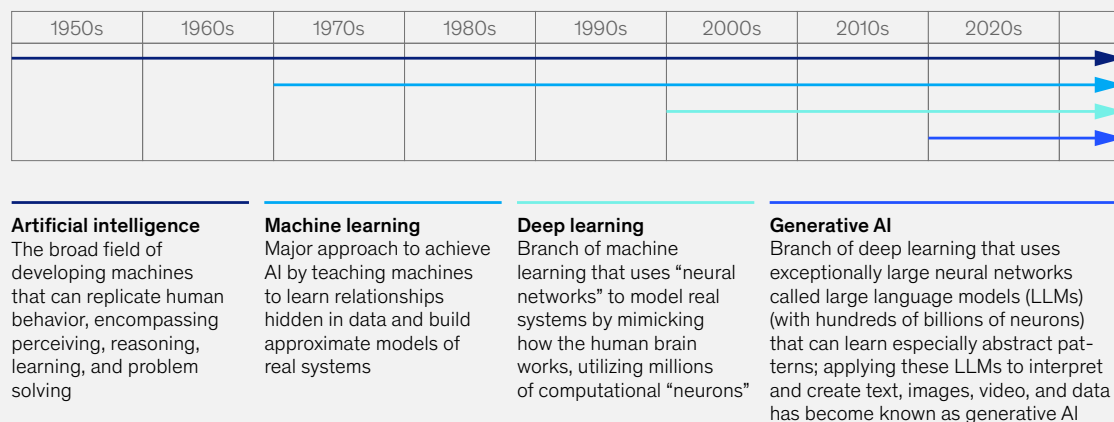
the database, often referred to as the large language model or foundation model.³

To pick or generate sequences of tokens, one deep learning model predicts subsequent tokens, while another analyzes and scores the selection—which is exactly why gen AI is often referred to as a generative adversarial network. This unique approach is what enables gen AI to begin to process troves of unstructured data to emulate true human reasoning and connection, synthesize insights, generate content, and generally “humanize” user interactions.

Exhibit

Generative AI is the next new frontier of a long AI journey.

Artificial intelligence timeline



McKinsey & Company

¹ “The economic potential of generative AI: The next productivity frontier,” McKinsey, June 14, 2023.

² “The great acceleration: CIO perspectives on generative AI,” MIT Technology Review, July 18, 2023.

³ “Embeddings: The Language of LLMs and GenAI,” Medium, October 4, 2023.

gen AI use cases for impact in as little as days or weeks—not months or years. Again, they’re able to do so because they’ve already built the necessary enablers: solid data and tech infrastructure, a strong talent base, and agile operating models.

They’ve coupled these enablers with clear business strategy and effective change management. Notably, Lighthouses avoid the trap of investing in technology for its own sake, instead ensuring that every use case presents clear business value.

Paradoxically, they've surged ahead by taking a patient, measured approach—typically between ten and 20 months for use case implementation, with an ROI period of approximately two and a half years. This takes patience and a steady hand, but the returns are worth it. Lighthouses' 4IR use cases have averaged between two and three times ROI within three years and between four and five times ROI within five years.

As Lighthouses continue to push through the scaling slump, their ability to implement use cases more rapidly is improving. The most recent three Lighthouse cohorts implemented use cases 26 percent faster than the first three did, and 75 percent of Lighthouses report that they're able to deploy a new advanced use case in under six months; 30 percent can do so in less than three months. Technology adoption is self-perpetuating. The more companies progress, the faster they progress. This also provides them with added agility and ability to respond to disruption—a major factor in the expanding performance gap between leaders and laggards.³

This moment compels a decision: Lead, innovate, or follow fast

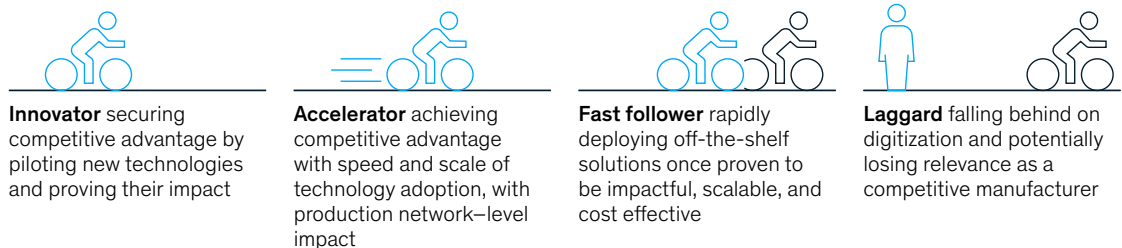
What does an inflection point mean for manufacturers? It compels a crucial decision about how to respond. The global front-runners—Lighthouses—along with an increasing number of other leading organizations are pushing through the scaling slump, achieving network-level impact. What will other companies do?

There is more than one intelligent response. An organization might choose to be a network-level digital *innovator*. This is an industry pathfinder that takes a risk on—and proves, at the factory level—the next big thing. This is the path that many Lighthouses have taken. But there's also a smart path forward for the industry *accelerator*. This company focuses on network-level impact, changing the landscape for an entire industry. Finally, there's great opportunity that lies with being a *fast follower*. This company embraces the playbook already written by the innovators and accelerators, capturing value while skipping the costs and tribulations of the learning curve altogether (Exhibit 4).

Exhibit 4

As Fourth Industrial Revolution technologies accelerate and Lighthouses tackle the scaling slump, others will need to take a strategic response.

Response archetypes



McKinsey & Company

³ Global Lighthouse Network 2023 Research Survey, August 2023.

Find more content like this on the
McKinsey Insights App



Scan • Download • Personalize



Each of these three responses can comprise an intelligent strategic response. This exciting juncture of the Fourth Industrial Revolution provides a momentous opportunity for manufacturers to choose a course of action. There's freedom in that, and it means that companies can take the approach that best suits their circumstances and business needs. But make no mistake: this inflection point also means that inaction is a sure-fire path to failure.

The next two articles in this series will explore what advanced AI and gen AI look like among today's leading manufacturers, and the capabilities that are powering Lighthouses to scale advanced technologies across full production networks.

This article originally appeared in the Global Lighthouse Network whitepaper Adopting AI at speed and scale, published on December 14, 2023.

Henry Bristol is a consultant in McKinsey's Dallas office, **Enno de Boer** is a senior partner in the New Jersey office, **Dinu de Kroon** is a partner in the Zurich office, **Forest Hou** is a partner in the Shanghai office, and **Rahul Shahani** is a partner in the New York office. **Federico Torti** is the advanced manufacturing and supply chains initiatives lead at the World Economic Forum.

Designed by McKinsey Global Publishing
Copyright © 2024 McKinsey & Company. All rights reserved.