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Ingenuity for life



The race to a digital future

Assessing digital intensity
in US manufacturing

Executive Summary

Manufacturers of all kinds have significant progress still to make as they move toward a digitally enabled future.

Outliers such as California-based electric car-maker Tesla, which uses in-vehicle data analytics, advanced automation and robotics, and even a custom enterprise resource planning (ERP) system,¹ remain by far the exception, not the norm. For most other manufacturers, this research highlights clear gaps across all six core digital categories (see below), with no one sector scoring 60 or higher out of 100. In particular, areas such as connectivity (embedded sensors to connect equipment and output) and adaptability (digital design and modeling, and the ability to customize production) need further improvement.

The six dimensions of digital

Our research evaluates manufacturers' digital capabilities across the following core dimensions, using their relative progress in each to provide an overall score out of 100.

- **Data intensity:** data strategy, data collection, storage and analysis, and data-driven decision-making.
- **Connectivity:** sensor usage in production and output, and networking of production equipment and plants.
- **Adaptability:** customization capability, design and modeling, and robotics.
- **Integration:** enterprise and supply-chain data integration.
- **Security:** strategy and systems implementation.
- **People:** leadership, skills and training.

Our research shows that manufacturers fall into two camps of adoption: the 'Efficiency Experts' and the 'Revenue Re-inventors'.

Both groups are deploying digital technologies to improve productivity and efficiency, but the latter is leading the way in exploring how digital can be progressed even further – to transform their business model and unlock new markets.

Firms in the Revenue Re-inventors group are more likely than Efficiency Experts to say that their financial performance is ahead of their peers. In particular, Revenue Re-inventors are more likely to create new revenue streams from the provision of digital services – as Rolls-Royce has done through its Engine Health Management service, which uses onboard sensors and live satellite feeds to track the health of thousands of engines operating worldwide.²

One key reason for manufacturing's relatively slow progress on digital is fears over cyber-risks. This is especially true now, following various high-profile breaches, and some industry experts point to manufacturers as prime targets for hackers.³ "Security is another breakpoint keeping manufacturers from moving faster with digitalization," explains one industry expert. As a result, leadership on digital issues among the companies polled for this research is often strongest from a risk perspective – as opposed to being more focused on the upside opportunities.

Data remains a blind spot for many manufacturers. While a plethora of companies in other industries have exploited data to create significant new revenue

sources, there is little evidence that industrial firms have got to grips with their data. As one executive puts it in this report, “Data is the gold of the 21st century” – yet few manufacturers have learnt the art of prospecting for this precious resource.

About the research

Our research surveyed 209 senior executives and directors of large US manufacturing organizations to understand the progress of digitalization among discrete and process manufacturers. Over **80%** of companies surveyed reported revenues of up to \$10 billion a year, with the balance (**18%**) reporting revenues in excess of \$10 billion. The research was conducted by **Longitude Research** on behalf of Siemens.

We would like to thank the following interviewees for their time and insights in shaping these findings (listed alphabetically, by surname):

- **Dean Bartles**, Founding Executive Director, Digital Manufacturing and Design Innovation Institute
- **Raj Batra**, President, Digital Factory Division, Siemens USA
- **David Greenfield**, Director of Content and Editor-in-Chief, Automation World
- **Carsten Maple**, Professor of Cyber Systems Engineering, Warwick Manufacturing Group Cyber Security Centre, University of Warwick
- **Cliff Waldman**, Director of Economic Studies, Manufacturers Alliance for Productivity and Innovation (MAPI) Foundation
- **Mike Williams**, Independent Executive Consultant, Modern Automation Consulting Services
- **Prof. Detlef Zühlke**, Director of the Innovative Factory Systems Research Department at DFKI, the German Research Center for Artificial Intelligence

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- 1 https://www.capgemini-consulting.com/resource-file-access/resource/pdf/tesla_motors.pdf
- 2 <http://www.rolls-royce.com/about/our-technology/enabling-technologies/engine-health-management.aspx#sense>
- 3 <https://www.autoindustrylawblog.com/2015/03/19/the-auto-industry-the-next-big-target-for-hackers/>

Introduction

The case for digitalization

Many cutting-edge manufacturers believe we are in the middle of a fourth industrial revolution, or Industry 4.0. They say that, just as steam power, the assembly line and computer-powered automation ushered in new eras of productivity for manufacturers, a new generation of digital technologies has the power to radically transform the way goods are produced.

Increased connectivity, greater adaptability

Sensors and machine-to-machine communication, for example, are increasingly being used to reduce maintenance costs and improve uptime. Yet these technologies also enable manufacturers to innovate 'products as services' – such as a fridge that senses when its owner is out of milk and automatically orders more.

These opportunities are not confined to consumer products: suppliers in the energy sector are using connected technologies to fundamentally transform the service they provide to their customers. Pacific NW Smart Grid Demonstration Project, for example, has dramatically enhanced power-grid reliability and performance by embedding responsive assets throughout the power system.⁴

3D printing is also empowering a growing number of firms to drive huge productivity and efficiency gains by instantly developing and testing prototypes – thereby removing entire stages in the supply chain. And, taken beyond the factory floor, 3D printing is enabling some firms to provide their customers with an entirely new, highly personalized service. For example, Confederate Motors' collaboration with 3D Systems' Quickparts has given the bespoke-motorcycle maker the ability to turn even the most wildly imaginative designs into physical reality.⁵ 3D Systems provides a one-stop shop for hundreds of prototypes, molds and production parts – from the intake manifold to the key that starts the motorcycle.

»All firms are on the digitalization path, because eventually they will all need to digitalize. The question is, how fast will they get there?«

Walt Boyes, Principal,
Spitzer and Boyes

Dual benefits of digital

Rather than one single technology, though, digital is diffuse – spanning data and analytics, cloud computing, the Internet of Things (IoT), and more.

For most firms, the benefits of digital technologies fall into two core categories: improving efficiency and driving transformation – such as by creating new products and services. Both are critical to increasing competitive advantage and driving growth across the top and bottom lines. With the right strategy, these benefits can be achieved simultaneously.

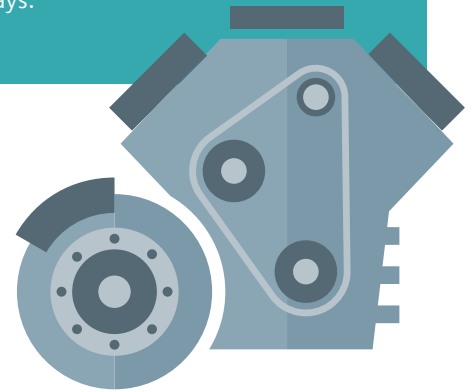
Manufacturers can also achieve the dual benefits of increased productivity and new revenue streams through augmented reality (AR). On the one hand, AR is enabling firms to deliver huge operational and productivity improvements by training staff in a more in-depth way, reducing maintenance times, and enhancing operational safety. But Fluxo Soluções Integradas, a Brazilian provider of automation and cogeneration in the renewable energy sector, has gone further and is using augmented reality technology to demonstrate its products to customers, enabling them to more easily understand the benefits of these complex industrial projects.⁶

Untapped potential

If the US manufacturing sector seizes the opportunities presented by digitalization, the expected impact on both efficiency and innovation is enormous. “There is a massive amount of potential,” says Raj Batra, President of the Digital Factory Division at Siemens USA. “According to McKinsey, digitalization offers the United States an opportunity to boost GDP by up to \$2.2 trillion by 2025. Industry will be a huge contributor to this growth.”

BMW Group harnesses big data to boost performance

Automotive giant BMW Group is using big data and analytics to detect vulnerabilities in its automobiles before they cause expensive problems in production.⁷ The company’s analysis combines data from test-drives of prototypes with information on thousands of faults recorded by vehicles and details from workshop reports. The results are immediately channelled back into the operational processes, helping to reduce error rates and save costs, as well as predicting and anticipating maintenance needs. It builds on the principles of Six Sigma, but on digital steroids: data evaluation that previously took months to complete is now available in days.



- 4 <http://smartgrid.ieee.org/newsletters/june-2012/largest-u-s-smart-grid-demo-project-is-set-to-roll>
- 5 <https://www.3dsystems.com/learning-center/case-studies/confederate-motors-works-3d-systems-push-limits-motorcycle-design-and>
- 6 <http://www.augment.com/portfolio-items/fluxo/>
- 7 <http://www.eweek.com/database/bmw-using-ibm-predictive-analytics-in-auto-production-repairs.html>

Driving efficiency, or reinventing the business?

While many firms have harnessed digital technologies to deliver incremental efficiency gains, few are unlocking the full potential of these technologies to create new revenue streams and maximize topline growth. Most US manufacturers, it seems, are still playing the short game.

Our research has identified two clear groups of digital adopters, which could be termed the 'Efficiency Experts' and the 'Revenue Re-inventors'.

Two faces of digital adoption

Efficiency Experts are pushing hard and fast on digital technologies such as connected sensors, virtual training, and artificial intelligence (AI). Their motivations for embracing these technologies are to increase uptime and efficiency and to keep their employees safe – in essence, to do what they do, but faster and cheaper. However, they identify themselves as behind their industry peers on data and financial performance, because they haven't yet fully realized the full benefits of their approach to digital and its power to transform the business.

By contrast, the Revenue Re-inventors identify themselves as both financially and digitally ahead of their peers, and find motivation for digitalization in opening up new markets and reinventing themselves and what they sell. They have a strong emphasis on data, and have established company-wide processes for analyzing the data they generate – not least to open up a new source of business.

As Carsten Maple, Professor of Cyber Systems Engineering at Warwick Manufacturing Group's Cyber Security Centre in the UK explains, digitalization technology can allow manufacturers to follow and learn from 'fast-fashion' retailers by using data to closely

»Eighty to 90% of the industrial base in the United States is composed of small and mid-sized companies. Many of these smaller businesses don't yet have a very good understanding of what these new technologies are, and what they're going to have to do in order to migrate to them.«

Dean Bartles, Founding
Executive Director of the
Digital Manufacturing and
Design Innovation Institute

Assessing digital intensity

To understand how far manufacturers have progressed with digital – and what they perceive to be the main benefits and opportunities of digitalizing – Siemens surveyed more than 200 US manufacturers. The results provide a comprehensive view of the level of digital intensity across five key industrial sectors: oil and gas, chemicals, food and beverage, aerospace and defense, and automotive.

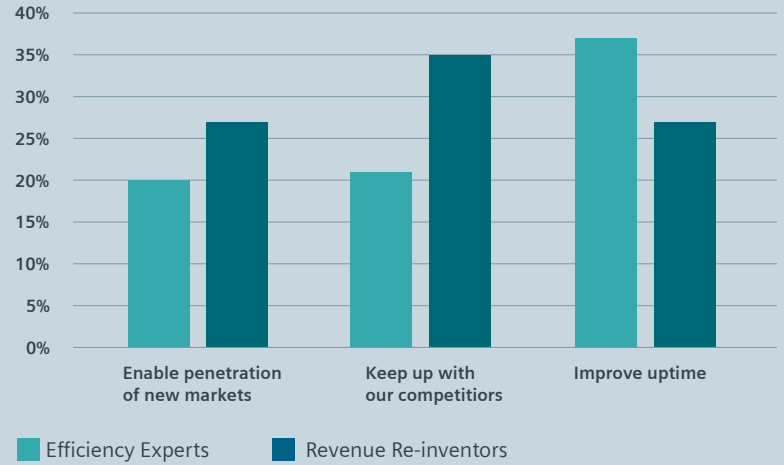
integrate their supply chains and respond rapidly to changes in consumer tastes: "This is precisely what Industry 4.0 was designed to do."

A pioneering approach delivers greater profits

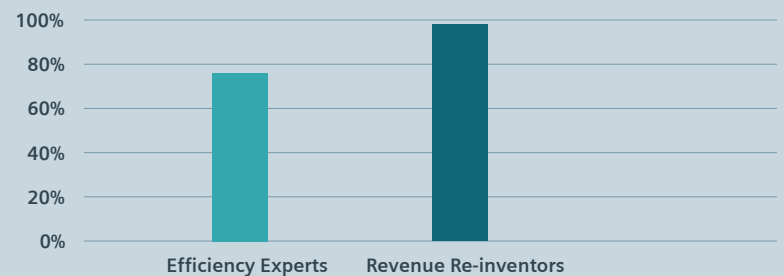
Revenue Re-inventors clearly stand out as the leader group in our survey sample. These firms are winning the race to a digital future: they are adopting new technologies not only to boost efficiency and drive productivity, but also to create new products and services that deliver sustainable topline growth. This bold, entrepreneurial approach is reflected in the strong financial performance they report.

At the same time, however, the research shows that overall progress on digital intensity remains limited across the survey group. This puts the entire industrial sector at risk – at a time when the USA is once again becoming an increasingly attractive manufacturing hub, thanks to rising costs in Asia and greater energy independence in the USA. "What's at stake with digitalization is the future of manufacturing competitiveness," says Dean Bartles, Founding Executive Director of the Digital Manufacturing and Design Innovation Institute. "Germany is ahead, and China is making a big move in this area. More and more countries are adopting these technologies. To remain competitive, US manufacturers are going to have to master digital technologies."

What are your top reasons for digitalizing?



"Our financial performance is somewhat or substantially ahead of competitors"



In focus: Two types of digital adopters

EFFICIENCY EXPERTS

Typically, firms in this category:

- » Are over 50 years old
- » Achieve annual revenues of less than \$5 billion
- » Say that their primary reasons for digitalizing are to increase productivity and uptime
- » Focus heavily on connected sensors and next-generation robotics
- » Report that their financial and digital progress is behind their peers'

REVENUE RE-INVENTORS

Typically, firms in this category:

- » Are under 50 years old
- » Achieve annual revenues of more than \$5 billion
- » Say that their primary reasons for digitalizing are to penetrate new markets and keep up with competitors
- » Focus heavily on cloud computing and advanced data analytics
- » Report that their financial and digital progress is ahead of their peers'
- » Have greater adaptability and can handle high-volume production for multiple customer groups

Learning from the leaders

Strikingly, our research reveals that increased adoption rates do not necessarily translate into better results.

Strikingly, our research reveals that increased adoption rates do not necessarily translate into better results. Rather, the most successful manufacturers are those which take a bold and strategic approach to deploying the digital technologies they do invest in, and use this to predict trends and identify new opportunities to delight customers.

Treating the enterprise as an integrated whole

Take sensors, for example. Efficiency Experts report that they have embedded sensors in a higher proportion of their production equipment compared with Revenue Re-inventors. Yet, despite this, the latter group collects a higher percentage of the data from its production processes and also reports higher levels of data integration – both across production processes within each plant, and across company plants. They are also far more likely to have developed a data management strategy for their production operations. This suggests that the Revenue Re-inventors have looked beyond one of the primary application of sensors – to monitor and maintain equipment – and have done more to exploit their potential for enterprise-wide data collection.

According to Batra, increasing integration is central to realizing the benefits from digital. “The last thing you want to do is spend money on isolated, disconnected projects,” he says. “You want to look at the enterprise as an integrated whole. Becoming a digital factory can’t be done in a piecemeal way.”

Interestingly, both Efficiency Experts and Revenue Re-inventors recognize the benefits of taking data collection beyond the production line and are beginning to embed sensors in the end products. Airbus, for example, has a total of close to 6,000 sensors in each of its A350 planes. These sensors generate 2.5 terabytes of data per day and help oversee flight performance and future maintenance, as well as feed into future iterations of key components.⁸

Accurate forecasts, smarter supply chains

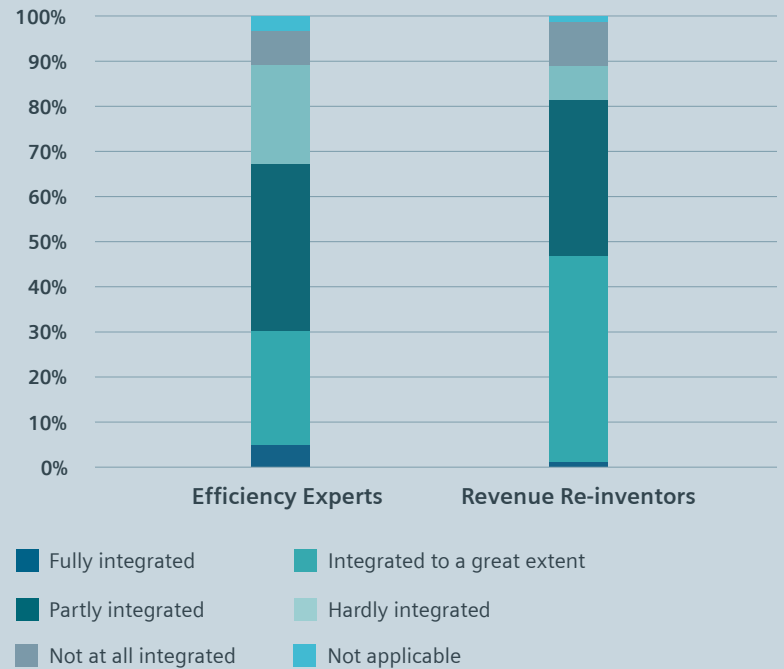
Revenue Re-inventors take a similarly bold approach to extracting value from the data they collect. While both groups analyze similar amounts of data, Revenue Re-inventors are more likely to use predictive analytics to forecast the performance of production equipment or processes in most or all areas of the organization, which is vital for reducing maintenance costs and decreasing downtime. They are also doing more to collect data from across the supply chain: **83%** have standard data collection and storage processes for both internal and external suppliers.

“When companies embrace a holistic approach so that they’re connecting everything from product design through production and services, they see dramatic gains in three key areas overall,” explains Batra. “First: time to market is being reduced by up to **50%** on a regular basis.”

Second: engineering costs can be cut by **40% to 50%**. Third: quality. In one of our own factories in Amberg, Germany, we produce 12 million automation components per year at a quality rate of **99.98%**.⁸

Another technology that is being adopted more rapidly by Revenue Re-inventors is 3D printing: over half of firms say they now use this technology in their operations. One of these is Dash CAE, a manufacturer of parts for high-end vehicles and a major supplier to the Formula One industry. With clients demanding shorter lead times and the costs of outsourcing growing, Dash decided to invest in its own 3D printing technology. Tim Robathan, the company's Design Director, says that in-house 3D printing has reduced its lead times by a staggering **83%**. "The manufacturing capabilities enabled by our 3D production systems allow us to produce tools for low-volume parts significantly quicker than any other manufacturing process, at a fraction of the cost."⁹

To what extent is data integrated across production operations within each plant?



"We use predictive analytics to forecast performance of production equipment or processes in most or all parts of the organization"



Efficiency Experts



Revenue Re-inventors

8 <http://www.datasciencecentral.com/profiles/blogs/that-s-data-science-airbus-puts-10-000-sensors-in-every-single>
 9 Quote sourced from: <http://www.stratasys.com/resources/case-studies/automotive/dash-cae>

Zones of struggle

Where digital adoption is lagging most

While it is clear that the deployment of digital technologies is well under way, our survey also highlights areas where many of the manufacturers surveyed – including Revenue Re-inventors – are struggling.

Dormant data and slow analysis

Much of the data that manufacturers collect goes unanalyzed. Less than a fifth (**18%**) of companies in our survey analyze more than **60%** of production data they collect, and this figure is similarly low among the leader group. As Automation World's David Greenfield puts it: "Large manufacturers in particular have been collecting tons of data for years. But only a few have decided what they want to do with it at this point."

Of the production data that does undergo analysis, timeliness is also an issue at many manufacturers. When it comes to maintenance, for instance, the ability to detect machining errors or component failures early can mean the difference between minor production delays and major downtime.

Real-time analysis of production data may be well in the future for most (less than **2%** of surveyed firms say that this is a reality for them today), but half of our sample say that it takes up to two days for production data to be analyzed for operational purposes, and over a third (**38%**) admit that the analysis gap is three days or longer. However, the case for real-time analysis differs between sectors.

"In the chemicals and oil and gas industries, there is a concept of time value of information," explains Mike Williams, Independent Executive Consultant for Modern Automation Consulting Services. "The time domain that you have to capture the information for a continuous process is 24 hours. For a made-to-order business, the time domain needed is the time it takes to make a batch. That could be minutes or hours. You need the information at the end of the specific time period to make any necessary correction decision."

»It's probably not surprising to see mid-sized companies delay in embracing new technologies, but even Fortune 500 companies sometimes hesitate. While you can't make a blanket statement about manufacturing in general, it's clear that there are many more examples of late adopters than of those running state-of-the-art technology.«

Raj Batra, President, Digital Factory Division, Siemens USA

Harnessing data to make better decisions

Given all of this, it should be no surprise that production decisions are only partly informed by analytics today. Even in the Revenue Re-inventors group, over half of firms report that few or no decisions are supported by robust data analysis.

According to Greenfield, manufacturers are using analytics mainly for the purposes of equipment maintenance. “Most examples that we see of people using advanced analytics or connected digital factory operations is around OEE [overall equipment effectiveness] and maintenance activities,” he says. “That is the low-hanging fruit that seems to be the most obvious place for people to focus on, even though there’s so much more to do.”

»If you use the ROI model and think only short term with benefits, you’re almost always going to choose not to invest.«

Cliff Waldman, Director of Economic Studies, MAPI Foundation

BP harnesses real-time drilling data to save millions

New technology platform BP Well Advisor (BPWA) is giving BP’s experts access to clear visualizations of vast quantities of real-time data. This allows them to spot potentially unsafe and costly issues before they happen, and to identify how to continually improve operational processes.¹⁰

BPWA uses a variety of sensors to capture high volumes of diverse data throughout the drilling process. Understanding this data allows BP to ensure that its process operates at peak efficiency and to respond quickly to issues such as ‘stuck pipe’, which can cost up to \$1 million per day in non-productive time.



The top five digital technologies implemented by manufacturers



Cloud computing



Connected sensors in plant operations



Connected sensors in products



3D printing



advanced data analytics tools

¹⁰ <https://tessella.com/case-studies/tessella-helps-bp-harness-drilling-data/#.V3vYw7grluU>



Dismantling barriers

So how can firms build on the progress they've made so far, and what are the biggest risks all manufacturers face as they develop their digital capabilities?

Our research reveals a number of challenges that producers need to overcome in order to advance digitalization. Some require industry-wide initiatives to be taken in collaboration with other manufacturers and industry stakeholders.

1. Develop and articulate a top-down digitalization strategy

Revenue Re-inventors are much more likely to have a fully developed digitalization strategy than the survey group as a whole, which suggests that it is crucial for manufacturers to develop a clear and compelling framework for digitalization.

In particular, firms should avoid mobilizing multiple small-scale initiatives which, while delivering short-term efficiency gains, fail to realize the long-term transformation required to stay competitive. According to Siemens' Raj Batra, "The best approach is to start with an overarching strategic plan that can be divided into manageable deliverables and scaled as needed."

As they develop their strategies, firms should also consider whether the classic ROI model is the most effective way to evaluate investments. "The regular ROI thinking that you use for capital investment doesn't completely translate in the case of new technology investment," explains Cliff Waldman, Director of Economic Studies at the Manufacturers Alliance for Productivity and Innovation (MAPI) Foundation.

"The 3D printer is very different from putting a new machine on a factory floor. It creates a different kind of supply chain, so your workforce is going to have to be reoriented to it. Then there are stranded costs, as you're going to have to leave your old technologies behind. If you use the ROI model and think only short term with benefits, you're almost always going to choose not to invest."

2. Nurture and attract the right talent

Skills shortages are acknowledged by more than half the survey group as a significant impediment to progress in implementing digitalization.

Aerospace and defense manufacturers appear to be able to attract the necessary data specialists and other digital skills to their production workforce – possibly due to the high-profile projects with which they are often associated. Many process manufacturers, however, struggle – especially those in the energy sector.

According to Waldman, companies will have to work fast to hire the necessary skills – and to train up the existing workforce. "If you didn't quite have the labor to work in a pre-3D printer, pre-robotics, pre-digitalization environment, you sure don't have the labor to work in what's coming quickly up the technology curve right now." Addressing this issue at the grass-roots level will help to fill the gap as skills requirements evolve.

And with the sector in such a state of change, skills requirements can shift radically. In the future, for example, computer-science graduates may have a better match to required manufacturing skill sets than engineers. “Ten years ago, the highest-paid job coming out of a four-year college degree was always engineering,” says the Digital Manufacturing and Design Innovation Institute’s Dean Bartles. “Now it’s computer science, because there’s such a high demand in manufacturing for people who have the ability to develop algorithms and code.”

3. Develop a set of common standards

Almost two-thirds (61%) of survey respondents highlight a lack of industry-wide standards for key technologies as hindering their digital progress. But looking at examples where digitalization has become the norm shows that as technology implementation gets more rapid, standards are a natural development. Manufacturers should do everything in their power to encourage the creation of such standards.

“Semiconductor manufacturers have set up their own standards in order to ensure that their systems are plug and play,” explains Professor Detlef Zühlke, Director of the Innovative Factory Systems Research Department at DFKI, the German Research Center for Artificial Intelligence. “Because of the need to replace technology every half year or so, developing standards became a key requirement for the sector. I believe this model can be used as a blueprint for other sectors as they look to develop their own common standards.”

4. Stay focused on cybersecurity

While 79% of respondents to our survey say that their company has a cybersecurity strategy in place, only 18% say that this strategy fully incorporates production operations.

While back-office systems have been connected to the internet for years, connected sensors in production equipment have only recently been introduced, exposing a key vulnerability among many manufacturers. They need to update their cybersecurity strategies to ensure that key infrastructure is protected from attacks.

Understanding where the vulnerabilities lie is key to this. In January 2016, General Motors (GM) went public with its plans to launch a security vulnerability disclosure program, which promises not to take legal action against ‘white-hat’ hackers who come forward with security flaws they discover in the company’s cars.¹¹ The hope is that hackers will be able to spot vulnerabilities such as the one found by a researcher in 2015 which enabled criminals to open a car or turn on the engine by hacking into GM’s OnStar RemoteLink app and OnStar service. Such disclosure programs are common in Silicon Valley, but are extremely rare in the auto world – only Tesla has a similar program.

¹¹ <http://arstechnica.com/security/2016/01/gm-embraces-white-hats-with-public-vulnerability-disclosure-program/>

Conclusion

From incremental gains to competitive advantage

Our research indicates that to be truly transformative, digitalization must be driven through a bold, enterprise-wide strategy that encompasses – but goes beyond – productivity and efficiency gains.

The most successful strategies will consider how digital can be married with the firm's existing capabilities to deliver compelling new products and services, ahead of competitors – even if this requires leaders to completely reshape the organization from the top down. US carmaker Ford, for example, is breaking into new territory with its 'smart mobility' initiative, which uses innovation and crowdsourcing to test breakthrough ideas for transporting people, goods and services.¹² Its goal is to predict what customers will want in tomorrow's transport ecosystem.

A 'leading from the front' attitude from the executive team will ensure that entrenched silos are broken down. "There must be real support from the CEO," says Zühlke. "If it is not there, you will have a really big problem bringing it to the lower levels of the organization." This view is reinforced by our research, with over **80%** of Revenue Re-inventors reporting fairly or extremely good levels of cooperation between internal and external stakeholders.

Until such leadership is in place, digital progress will remain slow and inconsistent. Deploying connected devices, for example, has become a relatively commonplace activity, and companies are becoming increasingly adept at collecting data from across the production line. But data analysis is where a critical breakpoint emerges: many firms do not have a clear understanding of, firstly, what insights they want to extract from the data and, secondly, how they will use these insights to drive continuous improvement across the organization. Having a solid strategy here will provide a huge advantage.

»Data analysis is where a critical breakpoint emerges. Having a solid strategy here will provide a huge advantage.«

Due diligence and leadership

Paying close attention to data management and cybersecurity is also crucial. Firms in our leader group were more likely to report that they have strategies in place in these two areas, as well as a fully developed and articulated strategy for Industry 4.0 overall.

A rising tide?

Our research shows that only the most advanced companies – the Revenue Re-inventors – are exploring how digital can augment the full breadth of their upstream and downstream systems. It may well be the case that these firms will act as a ‘rising tide’, pushing the smaller ships in the supply chain to increase their levels of digital adoption.

Despite the capability gaps highlighted, respondents overall seem fairly confident in their digital strategies: **48%** say they are somewhat ahead of their peers on applying advanced digital technologies to their manufacturing operations, and **17%** consider themselves to be substantially ahead. Does this mean that perceptions differ from the facts on the ground? Or perhaps that, in general, none of the sectors we evaluated in our survey have fully capitalized on the potential of digital technology? Only time will tell.



¹² <https://media.ford.com/content/fordmedia/fna/us/en/news/2015/01/06/ford-at-ces-announces-smart-mobility-plan.html>



Longitude Research

25 Sackville Street
London, W1S 3AX
Tel +44 (0)203 841 4770

Global Siemens Headquarters

Siemens AG
Wittelbacherplatz 2
D-80333 Munich
Germany

