Six levels of automation in component manufacturing

SANDVIK | EY Parthenon

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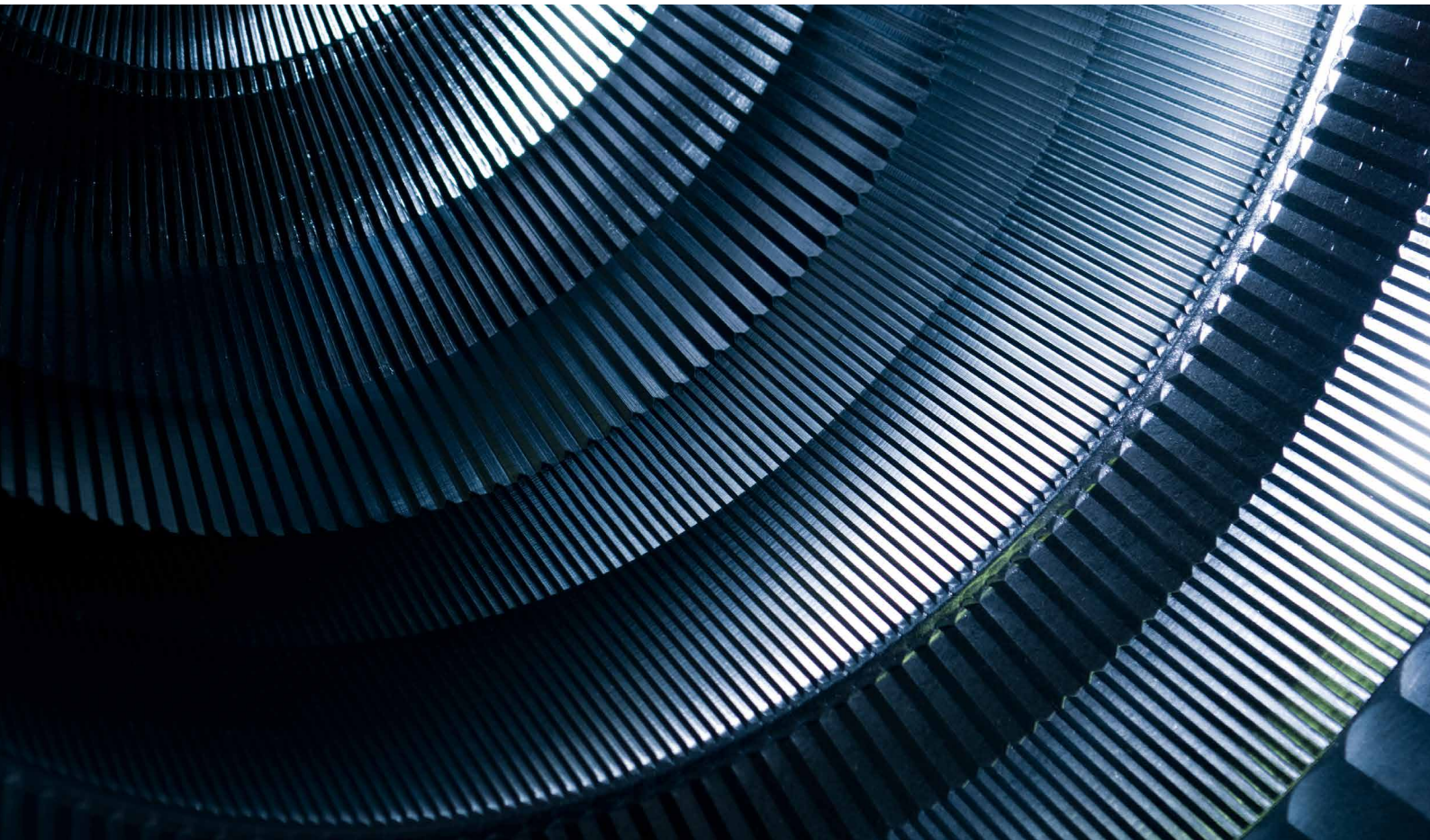
In the rapidly evolving landscape of modern manufacturing, the push toward greater automation and digitalization is stronger than ever. While frameworks like Industry 4.0 provide a broad vision, they often lack the clear, actionable steps that manufacturers need to assess their progress and plan future investments. This has led to fragmented implementations, where some plants — or even individual cells within a plant — operate with advanced technologies, while others remain rooted in traditional methods.

To address this, we propose a structured model akin to the six levels of autonomous driving. This model helps standardize how companies measure their manufacturing maturity and guide their evolution toward more automated and data-driven operations. It clarifies the steps manufacturers can take to transition from manual and assisted operations to highly automated systems, ultimately leading to fully autonomous manufacturing in the long term. By adopting this model, manufacturers can serve as a practical tool to help achieve greater maturity, ensuring that progress aligns with their long-term objectives.

To provide insights into the current automation levels and future ambitions among component manufacturers, Sandvik Manufacturing Solutions, in collaboration with EY-Parthenon teams, engaged 341 component manufacturers in North America and Europe. We explored their biggest challenges, their journey toward automation and their preferences for manufacturing software. The following sections present the key findings from the first part of our study.



About the study

341
Survey respondents

31
In-depth interviews

59%
in Europe

41%
in North America

Company size

28%
<100 FTEs

29%
100-500 FTEs

29%
500-5000 FTEs

14%
>5000 FTEs

End-user industry coverage

Aerospace | Die and mold | Energy | Automotive | Space and defense

General engineering | Medical

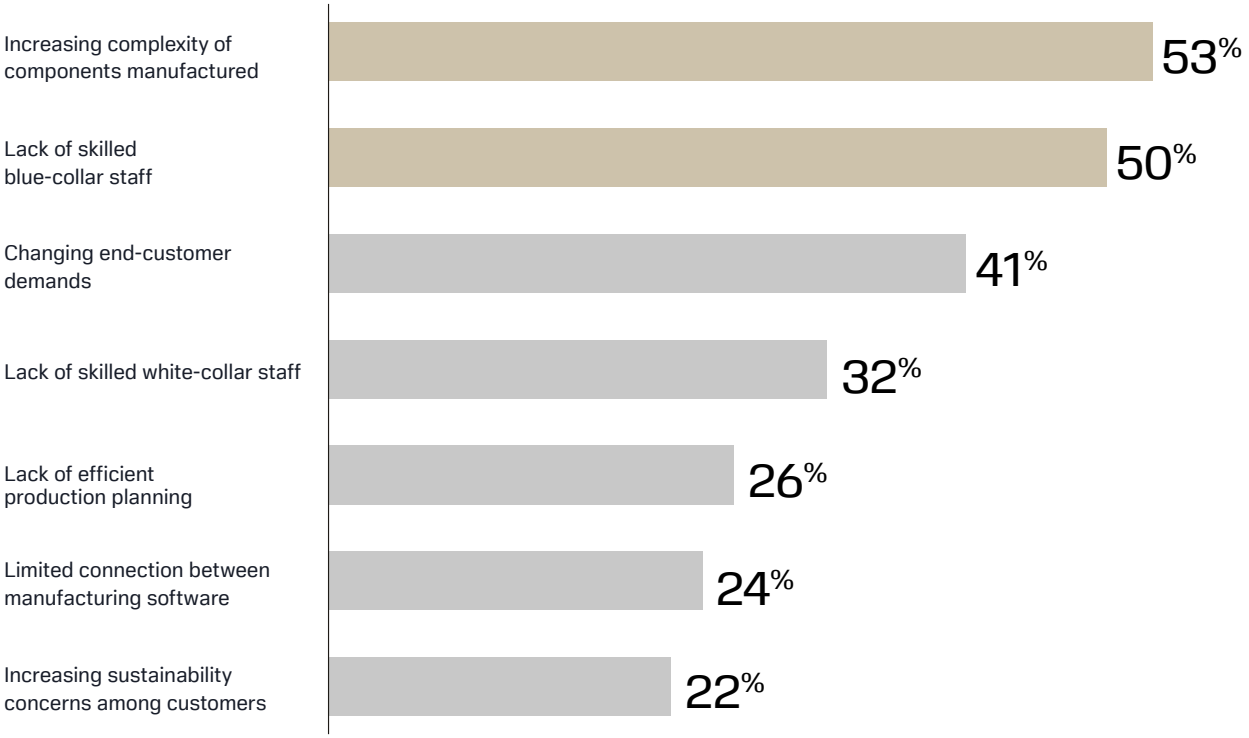
Component manufacturing

Component manufacturing involves the creation of individual parts that are assembled to form final products. This process encompasses a range of techniques, such as machining, injection molding and forming, and can be applied to various materials, including metals, plastics, ceramics and composites. The companies in this industry are diverse, ranging from small, family-owned machine shops to large, global manufacturing enterprises.

Production challenges

When assessing component manufacturers' top manufacturing challenges, the two main production-related challenges were component complexity and labor shortages. Increasing customer requirements are driving greater component complexity and changing demands. The lack of skilled labor is evident both when it comes to blue and white collars. These challenges were by far the most mentioned, well ahead of other issues such as deficient systems, poor planning and lack of data.

What are the most prominent production-related challenges in your component manufacturing?*



*Maximum three answers selected by each respondent

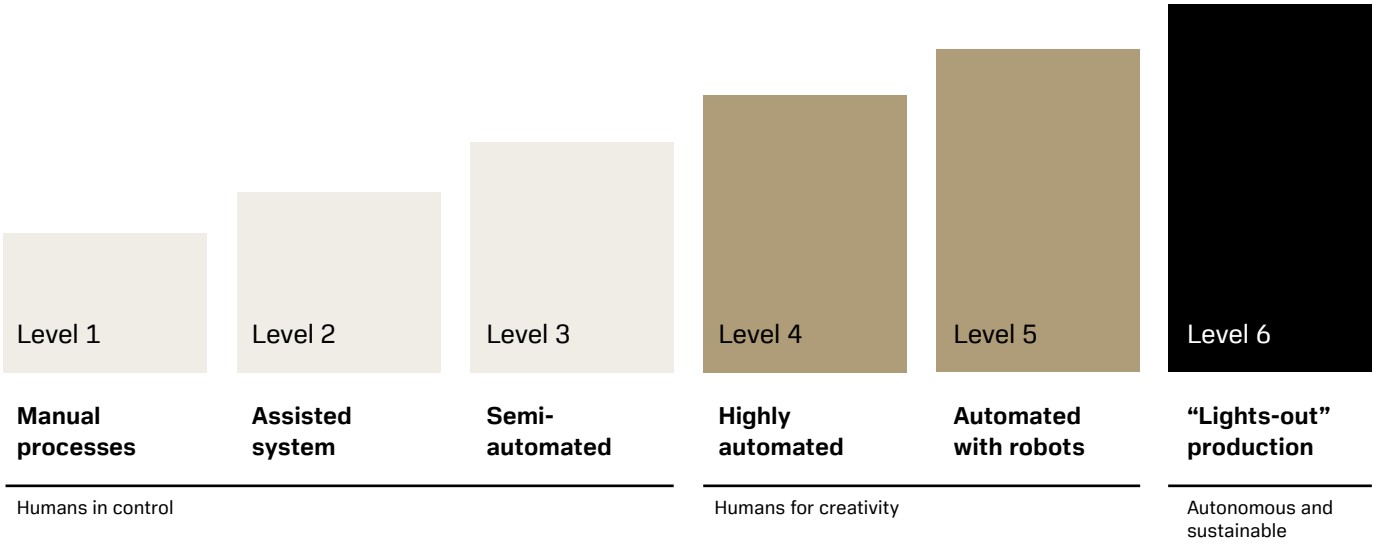
”The staff shortage is exacerbated by senior machinists retiring earlier after the COVID-19 pandemic , creating a large skill gap that is difficult to fill with junior staff due to the length of training required to meet our needs.”

Chief engineer, aerospace component manufacturer, UK

”In both design and production phases, customer demands in terms of new requirements and faster lead times imply challenges.”

Toolroom manager, micro molds manufacturer, US

Six levels of automation



Leveraging a six-level framework, inspired by the Society of Automotive Engineers (SAE) Levels of Driving Automation, the ambition was to understand where component manufacturers are today and their ambition levels going forward. The six levels are explained below.

Definition of automation levels

— **Level 1**
Manual processes: Companies depend heavily on human resources, with basic support systems providing limited assistance. Operators perform all changeovers, monitoring and process optimization with no unmanned production. Limited supporting software with no or minimal data exchange and simulation or optimization capabilities.

— **Level 2**
Assisted systems: Limited unmanned production at the cell level. Manufacturing software is used to some extent to optimize production flow, e.g., through simulation. Systems and data can be exchanged through file import and data mapping.

— **Level 3**
Semi-automated: Unmanned production at the cell level, with operators taking control when issues arise. Manufacturing software supports connectivity, resource planning, simulation and data-driven optimization at the cell level. Humans remain in control, with limited time for creativity.

— **Level 4**
Highly automated: Key processes across cells are automated, supported by, for example, automatic work-order routing, material flow as well as digital thread and digital twin simulations to optimize outcomes. People can gain insights into incremental improvements through recommendations. Humans are in control but can spend more time on creativity.

— **Level 5**
Automated with robots: Fully automated, online-level production, supported by robots for automated changeover processes and integration of systems across design, production and inspection to allow for real-time feedback and adaptation. Humans remain in control but primarily focus on creativity.

— **Level 6**
“Lights-out” production: Fully autonomous processes with no human intervention at the factory level, across all production lines. Unmanned production across shift levels, with a full digital thread for manufacturing that allows for continuous automatic design, predictive maintenance and manufacturing optimization. No human intervention is required on the production floor.

Automation maturity today

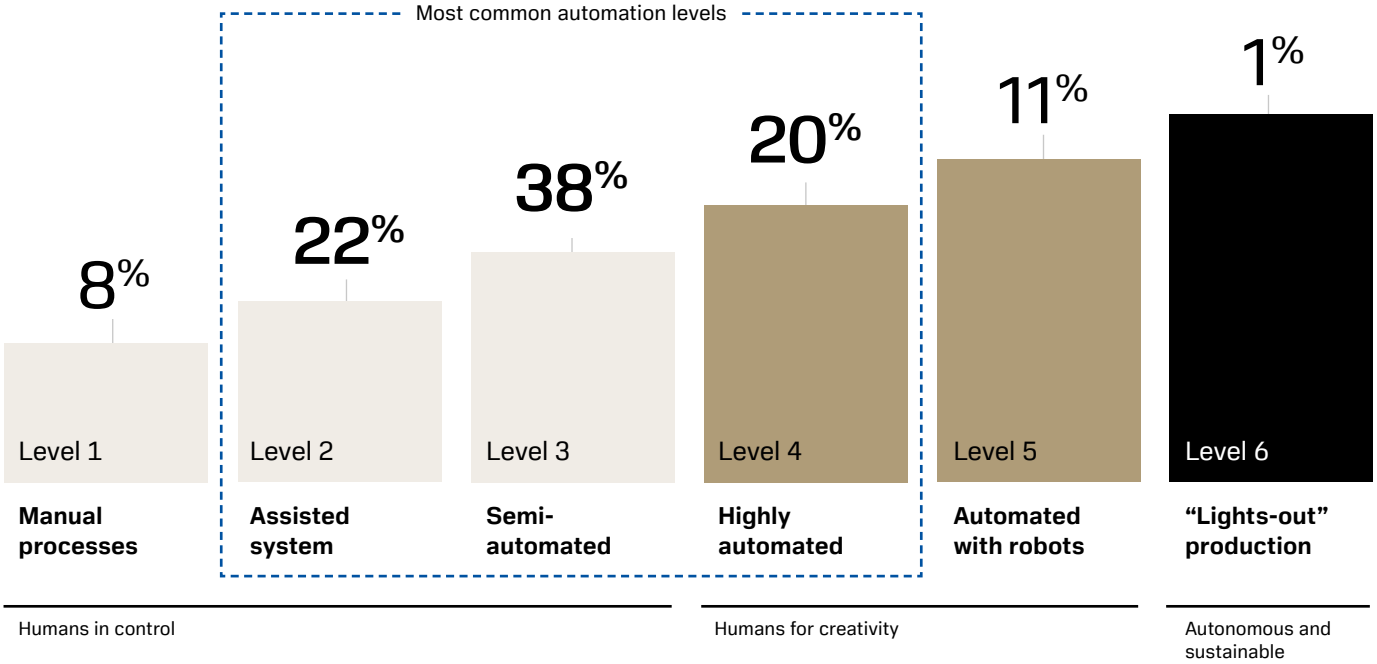
We asked respondents to conduct a self-assessment of the site where they work. Levels 2 and 3 were the most common responses. Nearly four out of 10 respondents rated themselves at Level 3 (semi-automated), with a frequent comment being that while automation of individual cells is high, the connection is lacking and represents the next step in their automation journey.

Automation maturity increases with company size. Levels 1 and 2 are most common among small companies and gradually decrease for medium, large and enterprise-sized companies. Conversely, Levels 3, 4 and 5 are common among enterprise-sized companies and gradually decrease for large, medium and small companies, respectively.

European companies rate themselves slightly higher than American companies: 75% of European companies rate themselves at least at Level 3, while 64% of American companies do the same. The median and average maturity levels came out quite advanced. For example, more respondents rated themselves as automated with robots (including inspection) than those with very manual operations without unmanned production. It should be noted that this rating is a self-assessment, which may lead to an overstatement of average maturity, for example by assessing the site's most advanced production line.

Breaking down production-related challenges by automation level, there are clear changes as the automation levels increase. For the two most manual levels, 1 and 2, there is a strong dependency on having the right employees.

What is the current level of automation at your manufacturing site?

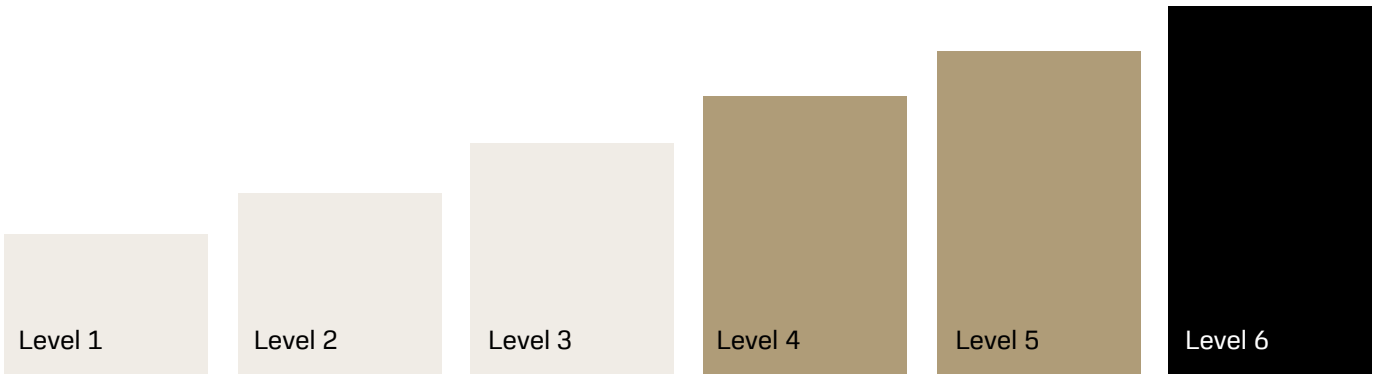


”Training staff is an enabler as well as a key constraint toward increasing automation. The people we hire from school only know the most basic things, and need to be trained in using more advanced solutions.”

Mill programmer lead, general manufacturer, US

As automation levels increase, customer requirements become the largest challenge, especially the increased complexity of components. For the three most advanced automation levels — representing approximately one-third of respondents — one issue that does not directly impact automation efficiency and costs has entered the top five challenges: sustainability. This indicates that unless you have the basic assets such as data connectivity, resources and systems in place to run your operations competitively, there are limited resources to address sustainability requirements.

What are the most prominent production-related challenges in your component manufacturing?



Large dependency on skilled staff for companies with lower automation.

Less dependency on staff due to higher automation which shifts focus to customer-related challenges; however current industry wide labor shortage impacts all companies.

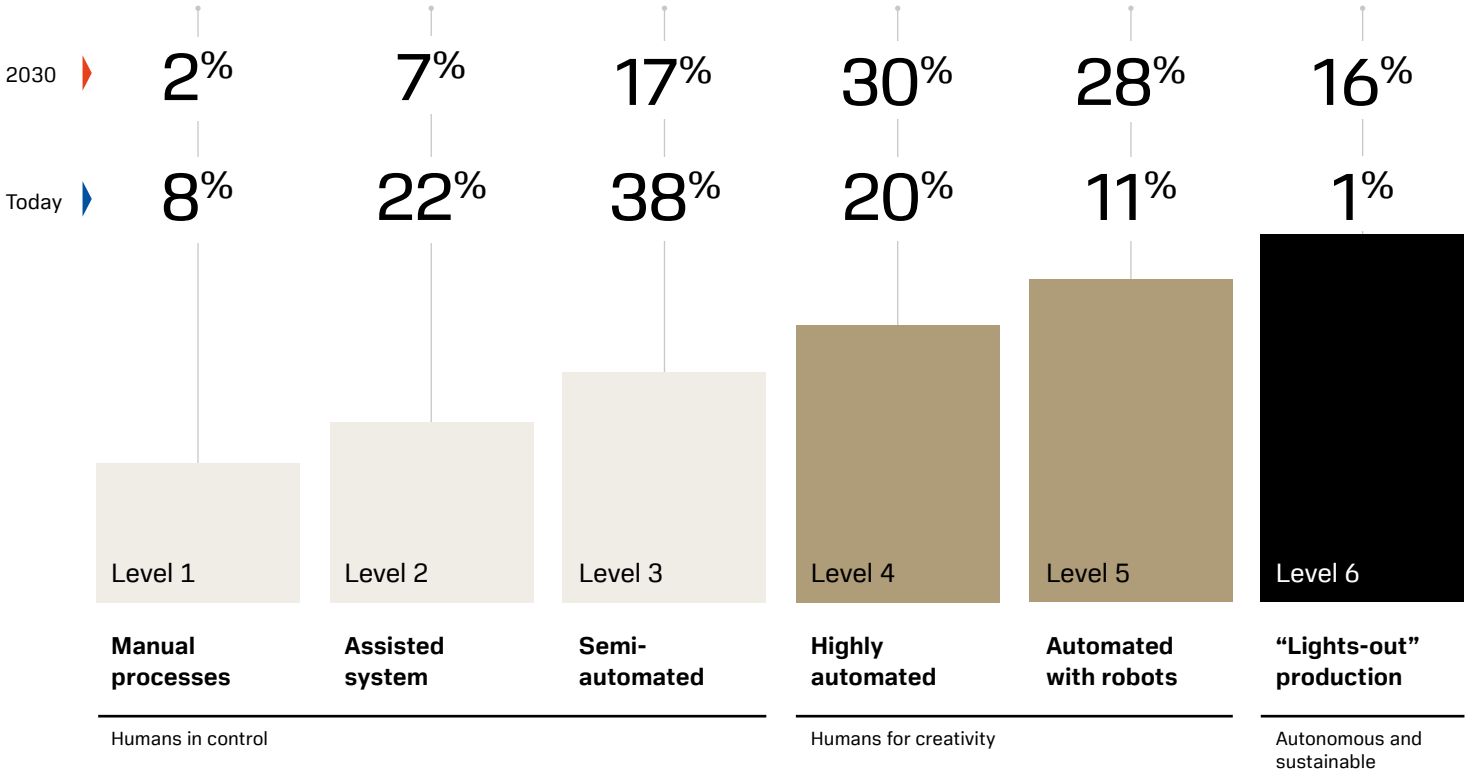
With the automation foundation in place, companies can focus on more operational distant challenges (e.g; sustainability).

Automation journey toward 2030

We have learned how component manufacturers view their current level of automation. But what are their plans for the rest of the decade? What is their improvement ambition?

If we simplify, 80% of component manufacturers plan to improve their automation. On average, companies aim to move up one step on the automation maturity ladder, with expected increases spanning from 1.2 to 1.4 steps for the first four automation levels. That said, a significant portion of respondents are aiming for two or even three-step improvements.

What do you expect the level of automation to be at your manufacturing site in 2030?



”Going forward, we will increase the level of automation but mainly from a non-physical perspective. The physical product flow will be kept at Levels 3-4 since we do not see the economic business case from automating this further.”

Business development and strategy manager,
bearings manufacturer, Germany

”We are currently at Level 3, with one automated cell producing medium to high volume batches of our standard products. Our target is to reach Level 5 by continuing to automate cell by cell as well as automating the CAM and CMM programming.”

Senior CAM engineer, mechanical seal manufacturer, UK

Enablers to increase the level of automation

What are the most important enablers of automation? What kind of support are component manufacturers expecting from our industry? The answer varies depending on the level of maturity, but at an overarching level, it comes down to having the basics in order: the right equipment, the right data collection from the equipment, as well as employees with the right skills to use the equipment and systems, supported by feedback loops for continuous improvement in a lean fashion.

A key factor in understanding automation levels is the ongoing trend of decreasing batch sizes in western manufacturing. High product mixes lead to non-standardized processes, which are challenging to automate in a financially viable way.

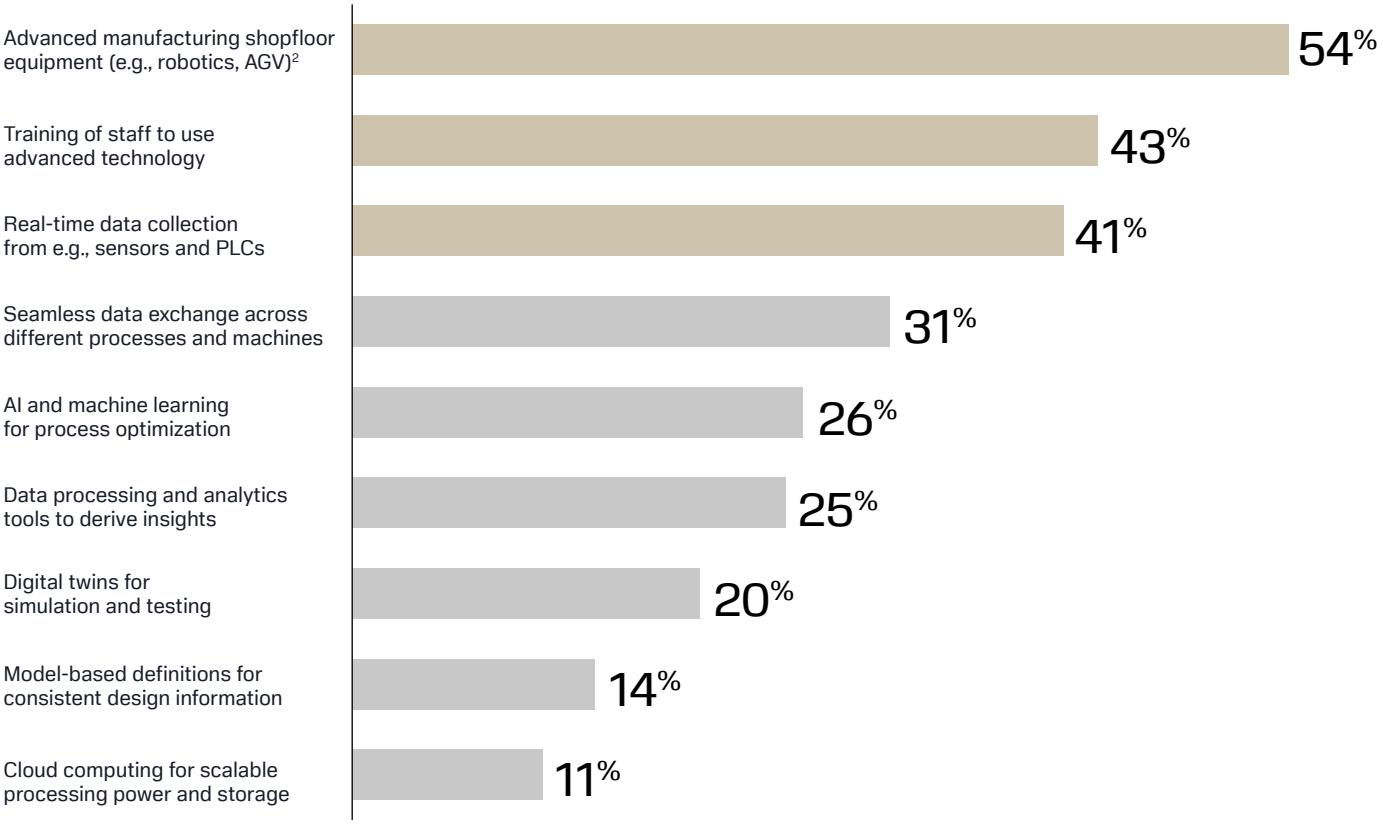
”A high mix of products limits automation possibilities, as it makes it difficult to set up a robotics cell to handle a large number of different scenarios.”

Supervisor CNC manufacturing, aerospace part manufacturer, US

”We do not have any integrations in place; different solution providers are keeping things separate. CAD and CAM integration is definitely the most important one.”

Mill programmer lead, general manufacturer, US

What are the most important enablers to increase the level of automation at your manufacturing site?*



Access to the right physical equipment on the shop floor is especially important for the lower levels of automation, ranking as the top enabler for Levels 1 to 4. For Levels 1 to 3, employee training consistently ranks as the second most important enabler of automation, while the data- and software-related enablers rank lower.

While this might seem counterintuitive — how can you automate without access to the right data and decision-making tools? It is natural that you first need the basic equipment, lean culture and necessary skills in place to start the automation journey.

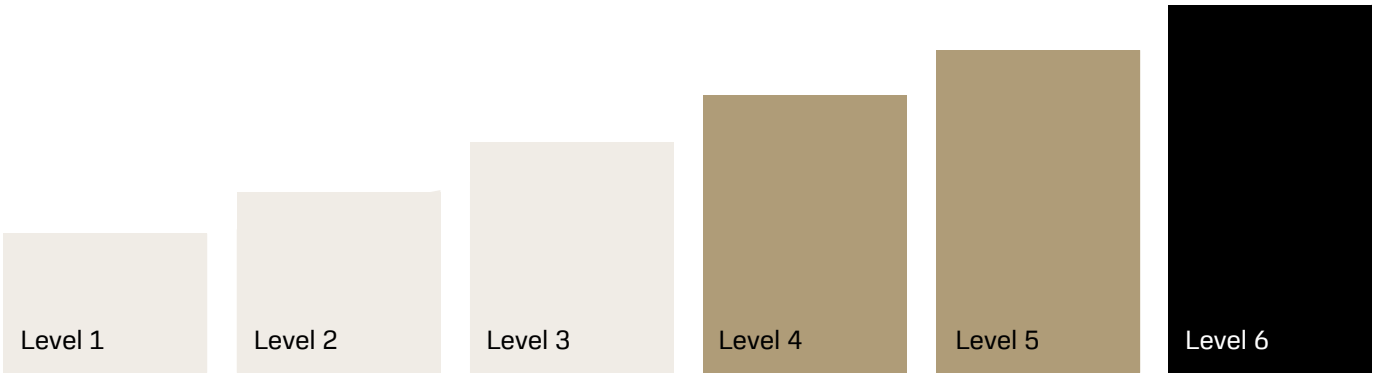
”Routing of the component, as well as CAM programming, are crucial for the throughput time and robustness of the process when making ‘one-of-a-kind’ components.”

Business development and strategy manager, bearings manufacturer, Germany

*Maximum three answers selected by each respondent

At the more advanced automation Levels 4 and 5, data- and software-related enablers become much more important, with real-time data collection and seamless data integration taking priority. Artificial intelligence (AI) is also emerging as a critical enabler. Generative AI has the potential to introduce a new level of intelligence in complex operations with large volumes of unanalyzed data. For the sixth and final automation level — though only a handful of respondents reported achieving this — AI is the most important enabler. This is not surprising, given that real-time data and seamless data exchange are more or less prerequisites for reaching automation Level 6.

What are the most important enabler to increase the level of automation at your manufacturing site?



Enablers for companies with low automation mainly relate to building the necessary internal infrastructure (e.g., equipment and training) to facilitate the transition.

Companies with higher automation shift focus from internal infrastructure enablers to digital ones to further improve automation and efficiency.

Summary

Customer requirements and a lack of skilled staff are the two main challenges facing component manufacturers. This is consistent across companies of all sizes and levels of automation, but with some important nuances.

— As automation levels increase, the skills shortage challenge decreases.
— The larger the company, the bigger the challenges posed by changing customer requirements. This is expected, as larger companies tend to produce more sophisticated parts and components.
— The smaller the company, the more severe is the blue-collar staff shortage. Larger companies have been able to build a more stable workforce over time, and compensate shortages by increasing automation.

Today, six out of 10 companies report operating at automation Levels 2-3. This indicates they have implemented limited to moderate automation, with some degree of unmanned production at the cell level. Approximately one-third of respondents consider themselves to be highly automated, with minimal human intervention in their processes. However, this assessment could be somewhat optimistic, considering average operations. Even for highly automated component manufacturers, a full feedback loop is rare, and automation is often uneven across the shop floor, with certain areas being more advanced than others.

Respondents indicated plans to advance their automation by an average of 1.3 levels. However, our discussions reveal that any automation improvements are closely evaluated from a cost-benefit perspective. While initial levels of automation are essential for maintaining competitiveness and reducing reliance on manual labor, the more advanced steps present significant challenges. They require substantial time and investment, and can be particularly difficult to implement in manufacturing environments characterized by small batch sizes, which is common for many companies in Europe and North America.

The best automation enabler is shopfloor equipment, e.g., robotics and automated guided vehicles (AGVs). This is not surprising, as these tools are necessary to take the first automation steps. Perhaps more surprising is that employee training ranks as the second most important enabler. This makes sense in the context of the ongoing skills shortage, especially among blue-collar workers, and the increasing complexity of shop floor equipment.

Data gathering ranks as the third most important enabler, which also makes sense. Without structured data, it is difficult to perform data analytics, simulations, or feedback-driven improvements. The relatively low importance placed on AI and digital twin technology could be explained by the need to reach a certain level of automation maturity, develop competence in using AI to help solve problems, and overcome vendor capability limitations before these technologies can provide significant value. This aligns with their increased importance as companies become more mature in their automation journey.

”We introduced generative AI a few months ago, and have started playing around with it to get familiar with what you can do with the AI concept. It is quite good on a general level, but you notice it has limited knowledge when asking more detailed questions.”

Mill programmer lead, general manufacturer, US

Most prominent production-related challenges among component manufacturers include:*

53%

increasing component complexity

50%

Lack of skilled blue-collar staff

The majority of component manufacturers are on automation levels 2 and 3 (limited to some unmanned production) out of six levels.

80%

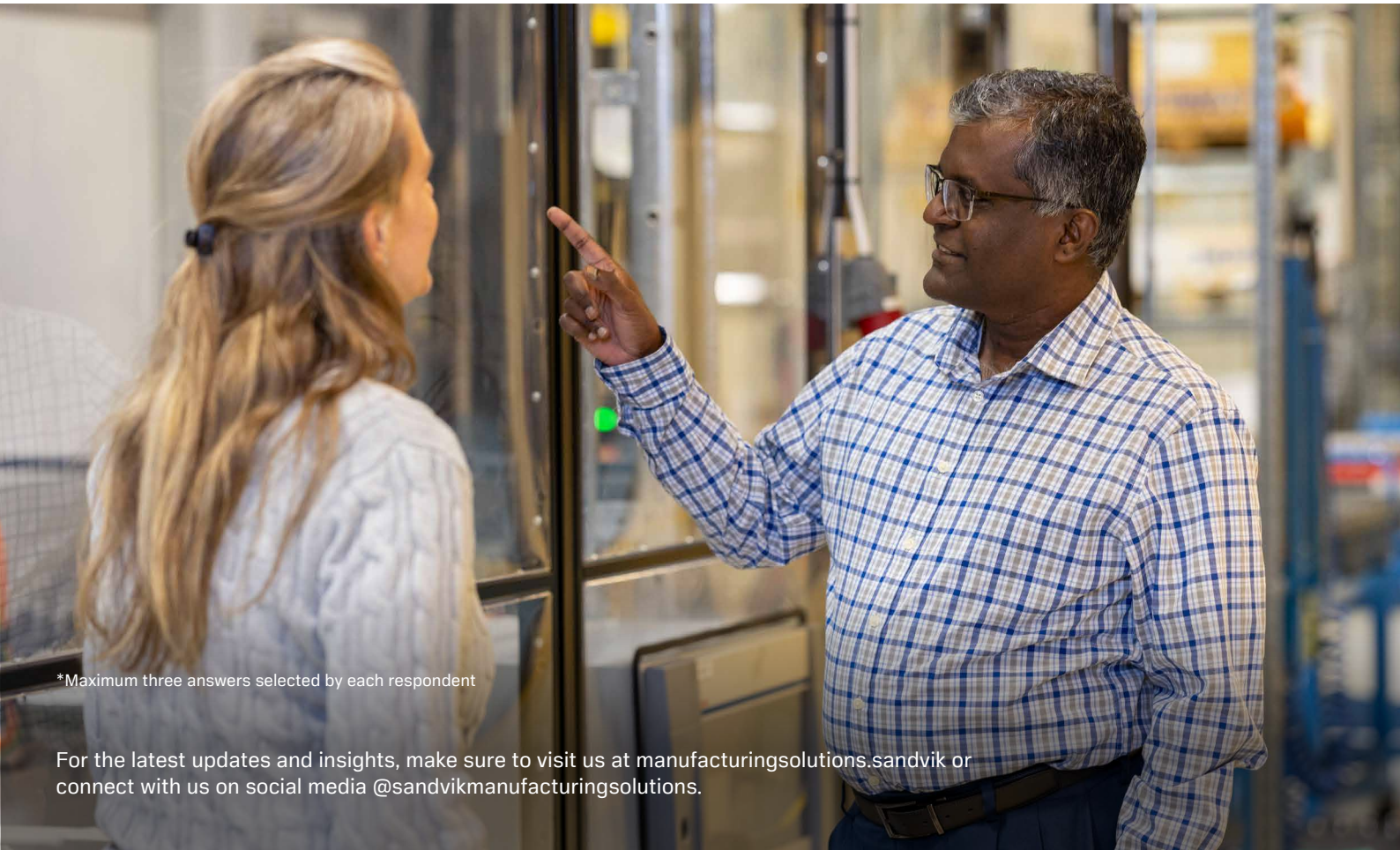
expect to increase the level of automation by 2030

Key enablers for increased automation include:

— advanced shopfloor equipment

— training of staff to use advanced technology

— real-time data collection



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