WHITE PAPER

Driving innovation, efficiency, and quality through advanced manufacturing solutions

Summary

As megatrends—such as geopolitical risks, climate change, and shifting consumer demands—are accelerating the manufacturing industry's transformation across the globe, the next era of manufacturing must be recognized as more than just an evolution in technology. According to the World Economic Forum, the Fourth Industrial Revolution "represents a fundamental change in the way we live, work and relate to one another. It is a new chapter in human development, enabled by extraordinary technology advances commensurate with the first, second and third industrial revolutions."[1]

For the manufacturing industry, achieving the full potential of this fundamental shift requires a combination of advanced technology, new business models, partnership innovations, and workforce training to deliver better business outcomes. To remain competitive, companies must adeptly navigate megatrends in the way they do business, even when those megatrends bring their own set of demands and challenges.

On the one hand, a company may seek to drive greater efficiency across operations, which means finding ways to move quickly and agilely. At the same time, that same company must bolster resilience to weather supply chain interruptions and respond to a dynamic business landscape. Moreover, they must find ways to become more innovative, sustainable, and inclusive—all resulting in a dizzying array of competing priorities.

Today's manufacturers require new capabilities, skills, organizational changes, and methods of collaboration throughout the entire value chain. Advanced manufacturing technologies and solutions deliver the capabilities that companies need to succeed in an ever-evolving landscape.

As far back as 2020, the World Economic Forum identified four durable shifts in manufacturing:

Agility and customer centricity
put at the centre of operations leading to faster recognition of customer preferences and corresponding adjustments of manufacturing flow at next-generation, small-scale modular plants

Supply chain resilience
as a competitive advantage requiring connected, reconfigurable n-tier supply ecosystems, regionalization and overall higher level of customization

Speed and productivity
attained through increased levels of automation and workforce augmentation, increasing safety and competitiveness in a society where continuous reskilling and mobility are becoming the norm

Eco-efficiency
as a must-have to stay in business and ensure compliance with an increasingly complex regulatory landscape

They described the four shifts as "proving increasingly relevant in light of unprecedented challenges" and "key to organizations' sustainability in the face of disruption."[2] Today, these four shifts remain as relevant as ever for companies to be competitive, resilient, and responsible as we move into the future.

In this paper, we walk through five use cases at Flex that leverage different toolsets, systems, business models, and approaches that address one or several of the durable shifts transforming the manufacturing industry. By leveraging advanced manufacturing technologies combined with innovative, human-centric, and data-driven decision-making, manufacturers can capture all four shifts: agility and customer centricity, supply chain resilience, speed and productivity, and eco-efficiency.

[1] https://www.weforum.org/focus/fourth-industrial-revolution

[2] https://www3.weforum.org/docs/WEF_GLN_2020_Four_Durable_Shifts_In_Manufacturing.pdf

Advanced analytics platform enables better decision-making

Data analytics and the ability to make informed, timely decisions are crucial to remain competitive, resilient, and agile in today's ever-evolving business landscape. At Flex, we recognize that data collection and analysis serve as the foundation for every system, and that leveraging advanced analytics results in optimized manufacturing processes and other systems-wide improvements so that we can meet our customers' volume needs while maintaining world-class product quality.

Using industrial sensors, manufacturers can measure various parameters such as vibration, humidity, temperature, pressure, and video and optics data. This wealth of information provides valuable insights into manufacturing operations and enables real-time data-driven decision making. Moreover, Internet-of-Things (IoT) platforms and data management solutions can be used to incorporate advanced analytics, machine learning, and failure analysis, among other capabilities. At Flex, we take this holistic approach to embedding advanced analytics into the manufacturing process, so that we can harness the full potential of the digital manufacturing ecosystem.

> **A World Economic Forum article about data analytics and the future of manufacturing[3] stated that:**
>
> To realize this vision of hyperconnected value networks, manufacturers must employ a large variety of data-and-analytics applications, such as predictive maintenance, advanced robotics, and tracking and tracing in supply networks. The underlying data assets are the lifeblood of these applications. This data can:
>
> - Provide actionable insights by discerning patterns from data through human analysis of reports and dashboards.
> - Predict future outcomes for business stakeholders to act upon, using advanced analytics on historical data.
> - Enable self-optimizing systems that take autonomous action through self-learning self-steering algorithms, with input from historical and real-time data.

At Flex, we deliver real-time analytics and control through a comprehensive approach to the industrial IoT ecosystem. By investing in an end-to-end ecosystem that encompasses data collection, advanced analytics, and real-time control, we drive overall efficiency gains, optimize manufacturing processes, and help our customers succeed.

Factory virtual operator increases speed and productivity in advanced manufacturing

Our site in Althofen, Austria is a high-mix low-volume facility serving customers with a portfolio of hundreds of highly complex projects. This means that in any given month, the site sees a monthly average of 900 changeovers.

That level of complexity can be difficult and time-consuming for human operators to manage, so the team sought to improve these processes by implementing a 24/7 Line Stop Assistant we named LISA. LISA is a propriety, virtual operator system with real-time access to all the data sources related to production lines.

LISA uses this data to halt misconfigured production lines, alerting the shop floor team to resolve errors before they get further downstream. LISA also identifies line operators and ensures that they are properly trained before configuring a line.

Since LISA's initial rollout in 2019, the Althofen site has seen improvements in changeover metrics by reducing:

↓ **10%**
Changeover time

↓ **85%**
Line clearance time

↓ **56%**
Quality related downtime

[3] https://www.weforum.org/agenda/2022/09/manufacturing-data-advanced-analytics/

Increasing accuracy and productivity for PCBA with AI for predictive maintenance

Flex produces thousands of printed circuit board assemblies (PCBAs) a month at our site in Zalaegerszeg, Hungary. PCBAs are necessary for all electronic products, making them a key element of nearly every customer design. With the complexity, quality, and volume that customers require, there is no room for error.

An error in one step of the PCBA process can have detrimental and costly downstream consequences in a highly automated Surface Mount Technology (SMT) production line. A pick-and-place machine, for example, can have hundreds of components to position on a printed circuit board before going through a reflow oven for soldering. If there are missteps in any part of the process—such as an incorrectly placed component—they can flow through to the testing or debugging steps before they are caught, at which point several stages will need to be fixed and repeated.

Additionally, if the cycle time of these machines are either too long or short, there is a possibility that a failure or other negative event will occur, which is why manufacturers must ensure that machines are behaving appropriately—and catch issues quickly when machines are not performing to standard. Many times, errors occur in a pattern, which can carry onto hundreds of units if not detected in time.

Traditionally, we leveraged advanced systems to collect data from the machines used for PCBAs, then analyzed the collected data to help better understand machine failures, maintenance, and anomalies during production. This meant that site operations were provided with insights after errors or issues had already happened—so preventative action was impossible.

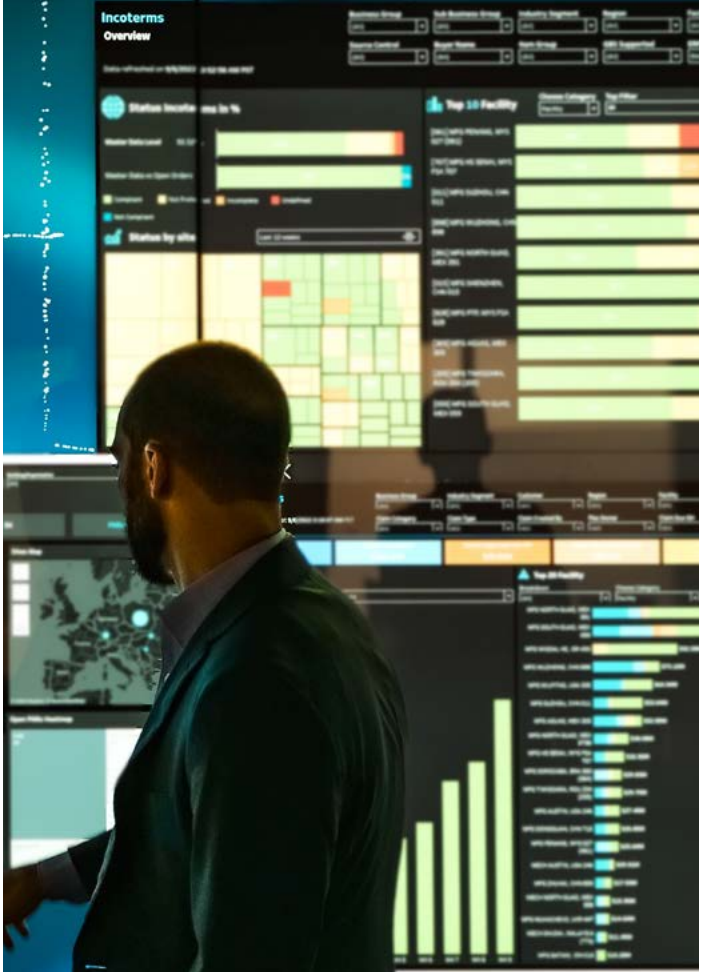
In 2023, Flex implemented a more proactive approach that allowed us to quickly collect and assess granular data so that we could act before problems arose or worsened. We developed deep learning models using generative AI to analyze the vast amount of historical data to predict anomalies, maintenance, and failures with localization before they happen. This new approach resulted in:

20-30%
Line utilization improvement by reducing downtime during the PCBA process

~33%
Increase of line operator productivity

25-30%
Increase of engineering team productivity

Supply chain visibility, resiliency, and risk management with digital tools



According to McKinsey & Company's Procurement 2023 report, "procurement leaders can combat volatility, inflation, and shortage and build resilience… by gaining transparency into the pressures they face," and that "building an agile procurement function with stronger links to internal and external partners is the key to success."[4]

That transparency and agility is what Flex delivers to customers through advanced digital tools that create the visualized data landscape required to properly evaluate, manage, and make smarter informed decisions resulting in improved supply chain resiliency.

Flex developed Pulse, a digital supply chain visualization tool that provides real-time visibility across 200+ data streams including transportation, manufacturing, and inventory. This level of data provides insights so that companies can mitigate potential risks before they turn into major disruptions. Pulse serves as a single source of truth, providing supply chain teams with the high-integrity, actionable data they need, with secure access to data from anywhere—whether it's a Flex Pulse center, factory site, desktop, or mobile device.

We've also implemented a Joint Risk Management (JRM) tool that harnesses artificial intelligence and machine learning (AI/ML) technology to help our customers design risk out of a product's bill of materials (BOM). With JRM, we collaborate with our customers to address supply chain risks and recommend mitigation options. The tool provides part-level insights at an early product lifecycle stage to avoid incurring larger negative impacts if risks arise in the product build or production stages. The JRM report typically contains:

- Part characteristics risks (e.g., compliance and end-of-life risks) and supply chain risks (e.g., lead time, stock out, availability, and escalation)
- An overall supply chain risk score for the BOM, which compares the BOM risks to other products within the same business units, as well as product-specific comparisons
- Suggested risk mitigation strategies and an assessment of the number of hours of engineering resources needed to improve overall risk score

These powerful digital tools enable companies to comfortably navigate the shifting business landscape, reduce risk, and make data-driven decisions to sustain a more responsive, resilient supply chain.

Realizing efficiencies and creating a safer, more inclusive work environment via automation and robotics

A Deloitte study stated that "autonomous robots can be used to improve the speed and efficiency of routine operations, particularly in warehousing and manufacturing spaces; work side-by-side with humans for added efficiency; and reduce the risk of employee injury in dangerous environments."[5]

[4] https://www.mckinsey.com/capabilities/operations/our-insights/procurement-2023-ten-cpo-actions-to-defy-the-toughest-challenges

[5] https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-manufacturing-autonomous-robots-supply-chain-innovation.pdf

In manufacturing, automation and robotics—including collaborative robots (cobots) and autonomous robots (AMRs)—can come together to optimize production while making the workplace safer and more inclusive. The use of robotics in tight spots, for example, frees human workers from dangerous or unpleasant tasks, while a robot that can lift heavy objects effectively removes the "ability to lift" requirement in many job description—enabling jobs to be filled by applicants with diverse abilities.

At Flex, AMRs are employed in advanced manufacturing warehouse facilities to bring supplies to automated manufacturing lines, move components from one location to another for the next steps, and transport the final product to the loading dock to be shipped to the customers. The robot operator assigns tasks, tracks its location, and responds to issues or obstacles via a tablet, smartphone, or computer. Data analytics are collected when the robot is operating and used to enhance performance and safety features for continuous improvement. A December 2023 McKinsey & Company report on warehouse automation stated that "emerging autonomous solutions (such as cobots mounted on AMRs) could help repurpose legacy infrastructure with enhanced technology."

Achieving sustainability benefits through advanced manufacturing

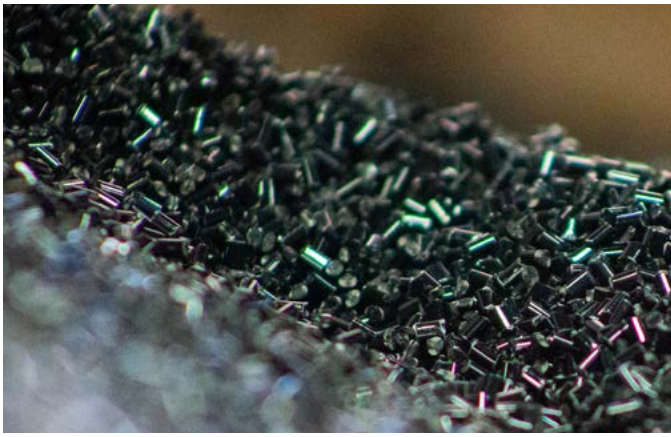
Another rising area of focus for companies is sustainability. A report by Gartner stated that "organizations are making aggressive and strategic sustainability goals to improve their brand reputation, ensure regulatory compliance and improve resource efficiencies."[6] The same report cited survey data demonstrating the top benefits to be derived from sustainability programs by 2025, including: increased company brand/reputation, improved resource efficiency, innovation and new products, improved customer satisfaction, and better risk management.

There's a sense of urgency in prioritizing sustainability as consumers, investors, and regulatory agencies continue to hold the brands they support to a higher standard. And while the benefits are myriad, companies may struggle with the learning curve and investments required to achieve sustainable design, sourcing, manufacturing, fulfillment, and after-market services.

At Flex, our sites around the world leverage advanced manufacturing technologies and solutions to not only deliver better business outcomes for our customers, but to also advance sustainable manufacturing and production.

For example, our site in Sorocaba, Brazil, has been recognized as a Sustainability Lighthouse by the World Economic Forum for its decade-long journey to introduce automation in multiple ways that enable circular economy solutions. The site has an integrated, automated material management system that identifies waste materials while ensuring sanitized recycling. The automated process—which involves digitization and IIoT—has resulted in a **94% reduction** of material waste and a **38% reduction** of plastic material costs. This performance management system also reduced the need for resources equivalent to 44,000 carbon credits.

By digitizing their circular economy system, the site in Sorocaba also was able to better measure sustainable impacts, including a **41% reduction** in scope 1 and 2 greenhouse gas emissions as well as a **30% reduction** in water consumption.



[6] https://emtemp.gcom.cloud/ngw/globalassets/en/doc/documents/744756-sustainability-a-customer-priority-and-provider-imperative.pdf

Conclusion

Organizations at the forefront of manufacturing's transformation recognize that addressing the four durable shifts—agility and customer centricity, supply chain resilience, speed and productivity, and eco-efficiency—is what will enable them to design, build, and deliver innovative, high-quality products at scale.

At Flex, we continually enhance our advanced manufacturing capabilities by investing in a focused portfolio of advanced manufacturing technologies and solutions—including simulation, automation, robotics, digitization, and additive manufacturing—while also embracing new business models and empowering our workforce. Doing so fuels our flexible, global manufacturing and increases efficiency and quality. Embracing advanced manufacturing in all its facets allows us to meet our customers' time-to-market, resiliency, sustainability, and end market requirements.

Let's work together to create the extraordinary

Working with a trusted manufacturing and supply chain partner like Flex allows you to move faster—through ideation, prototyping, engineering, manufacturing, value-added fulfillment, and circular economy solutions—while leveraging a broader set of expertise, capabilities, and scale.

For more information, visit **flex.com/connect**

Flex (Reg. No. 199002645H) is the manufacturing partner of choice that helps a diverse customer base design and build products that improve the world. Through the collective strength of a global workforce across 30 countries and responsible, sustainable operations, Flex delivers technology innovation, supply chain, and manufacturing solutions to various industries and end markets.