Modernizing manufacturing without disruption

How growing manufacturers can simplify complexity, improve asset utilization and strengthen day-to-day operations through practical technology investments.

Executive summary

Manufacturing today is under constant pressure to improve uptime, quality and operating efficiency while managing increasingly complex production environments. A factory's legacy technology estate may fall short of addressing the ever-rising expectations of customers and shareholders, not to mention competitive pressures. Modernization efforts that introduce instability, additional workloads or risks to production can be difficult to justify. Optimizing asset utilization to ensure maximum profitability is a key goal.

For these reasons, factory operators must seek clear outcomes from technology investments, such as more predictable operations, better quality and throughput, lower operating costs, and greater availability and resilience. But their progress toward these objectives can be slowed by fragmented systems, limited operational visibility and workforce constraints that make it difficult to scale improvements beyond individual production lines or plant sites.

This paper outlines a practical path forward for both discrete and process manufacturing. It explains how factories can improve everyday operations by modernizing their operational technology (OT) on the factory floor and enterprise information technology (IT) in ways that can more seamlessly integrate both to eliminate data silos.

Modern Infrastructure solutions help manufacturers scale and reduce complexity to deliver the workloads OT team members need to improve plantwide visibility. With that modern infrastructure, IT teams can then enable analytics and AI capabilities that support real-time decision making, boosting production efficiency, product quality, factory safety and bottom-line results.

Through examples such as predictive maintenance, AI-based quality inspection and energy optimization, this paper shows how manufacturers can use data and analytics to achieve these results. It also addresses the operational realities shaping the adoption of modern, data-driven manufacturing approaches, including skills shortages and the need to embed knowledge into systems rather than rely on individual expertise.

Modern infrastructure solutions can help manufacturers connect systems, manage data closer to production and evolve their production operations with confidence. The result is an environment that performs more consistently today while remaining adaptable as demands continue to change.

Outcomes manufacturers are working toward

To stay profitable and competitive, manufacturers must focus on outcomes shaped by day-to-day production pressures and returns on their capital assets. Predictable equipment uptime, consistent quality and reliable throughputs — often tracked together through metrics such as overall equipment effectiveness (OEE) — are at the center of manufacturing performance.

Avoiding disruptions. Whether unplanned downtime occurs in discrete or process manufacturing operations, it remains one of the most direct threats to performance goals, derailing production schedules, increasing per-unit labor costs and putting customer commitments at risk. In fact, manufacturers lose an estimated $50 billion annually to these disruptions.[1] Closely tied to improving equipment availability and asset utilization are gains in quality, yield and throughput.

Efficiency is always top of mind, too. Many manufacturers must operate increasingly complex environments as they adopt additive manufacturing, industrial IoT-connected equipment and advanced analytics, often with limited staff and while managing a mix of legacy and newer systems.

Innovative well-integrated technology solutions can simplify the addition of these capabilities while reducing the risks that can accompany doing so.

Playing it safe. Safety has long been inseparable from operational performance, with incidents causing their own production disruptions, not to mention personnel injuries, potential visits from regulators and even costly litigation. Research has shown that factories with good safety records outperform those with poor ones.[2] That's why manufacturers want to improve not only uptime, quality and throughput, but safety as well.

While manufacturers may have a growing interest in AI and analytics, they are understandably concerned about the best ways to implement these technologies. They want to see real investment returns via practical operational improvements without destabilizing production or increasing operational risk.

Why progress toward those outcomes often stalls

For many manufacturers, one of the most persistent barriers to improving plant performance is limited operational visibility. Production data generated by machines, sensors and industrial IoT-connected equipment often remains in silos spread across disconnected systems.

Industry research suggests that roughly two-thirds of plant-floor and supply-chain data is never analyzed,[3] leaving teams to make decisions with only partial views of what is happening in production. This lack of visibility often extends to production inputs and work-in-process inventory, leaving manufacturers carrying excess stock while still risking shortages — tying up cash and delaying replenishment signals to suppliers.

Removing blinders. Limited visibility also affects safety. When incident data, near-miss reports, and equipment condition information are siloed, hazards are harder to identify early, and corrective actions arrive too late. Fragmentation across systems compounds this problem. Many manufacturers operate with a patchwork of operational and enterprise technologies that were never designed to work together.

Studies cited in Dell manufacturing research indicate that industrial organizations typically manage dozens of disconnected OT and IT systems, even after investments in automation, manufacturing execution systems and analytics platforms. In such environments, improvements tend to be localized, and scaling successful practices across a single facility or multiple production sites can be slow and resource-intensive.

Turning dark data into operational insights

Manufacturing operations generate large volumes of data every day, much of which is collected automatically and then stored without being analyzed or used. This unused operational information is often referred to as dark data. It exists across systems, but remains difficult to access, connect or act on. Common sources of dark data include:

- Equipment and sensor readings
- Production and process records
- Supply chain and inventory data
- Workforce and safety information
- Customer returns and service feedback

When left untapped, dark data obscures insight. When made accessible, it becomes a foundation for better decisions and more predictable operations.

Reducing latencies. Constraints at the edge introduce additional friction. Manufacturing operations place real demands on reliability, latency and data security. Systems that depend on constant connectivity or centralized processing struggle to support real-time decision-making, especially in facilities with variable network conditions or physical constraints. These limitations make it harder to act on data while work is underway.

Staff skills and capacity compound these challenges. Many manufacturers must manage increasingly complex environments with limited internal resources. Specialized skills are scarce, and institutional knowledge is often concentrated in just a few individuals, many of whom may be nearing retirement. Introducing new tools or processes when teams are already stretched thin can introduce new production risks.

Taken together, these factors explain why plant modernization's progress toward better uptime, efficiency and resilience often slows. Investments are made, pilots succeed and isolated improvements appear, but without a way to connect systems, improve visibility and reduce operational overhead, momentum fades.

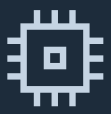
Rethinking modernization to improve day-to-day factory operations

To remove their modernization barriers, manufacturers should stop treating factory modernization as a series of isolated projects. Instead, they should focus on standardizing integrated technology solutions that can increase the interoperability and data sharing across systems, reducing or even eliminating data silos. The shift is less about adding new capabilities and more about creating consistency in how systems are deployed, connected and managed.

Streamlining operations. When factories operate on a common operational foundation, improvements become repeatable and scalable. Teams spend less time reconciling differences between environments and more time applying what works. Visibility improves because data follows in consistent patterns, making it easier to compare performance, identify issues and share practices across facilities.

Equally important is bringing compute and data closer to production, reducing latencies and better supporting deterministic, field-level signaling of actuators. Manufacturing decisions often need to be made at the edge while work is underway, not after information has been aggregated elsewhere. Processing data locally supports timely insight, reduces connectivity dependencies, and better informs faster decisions to optimize production further or mitigate issues as they emerge, before disruptions occur.

Strengthening the edge. Centralized systems still matter, but they are most effective when paired with local intelligence that supports real-time operations. Industry research shows that most organizations collect data faster than they can use it, a gap that widens when insights for decision support often depend on distant centralized processing.



Modern infrastructure for production and associated operations

Reliable manufacturing operations depend on compute and storage platforms designed to support industrial workloads, real-time data processing and predictable performance. Modern infrastructure provides a resilient foundation for production systems, data management, analytics and application performance across OT and IT environments.

Dell PowerEdge servers with Intel® Xeon® Scalable processors deliver real-time processing and deterministic performance for manufacturing execution systems, supporting low-latency analytics and automation at the edge.

Designed to evolve incrementally, these platforms support better availability, scalability, resource utilization and governance as workloads become more distributed — whether deployed on the factory floor, in on-premises data centers, in hybrid cloud environments or through flexible consumption models.

Manufacturers can modernize their infrastructure by taking advantage of Intel®-based Dell devices paired with Microsoft's Windows Server and Azure hybrid services, including:

- **Dell PowerEdge servers:** Core compute for manufacturing execution systems, analytics, virtualization and data-intensive workloads. With Intel® Xeon® 6 processors, PowerEdge servers handle data-heavy workloads with ease, maintaining speed and reliability when it matters most.
- **Dell PowerStore and PowerMax storage:** High-performance, resilient storage for operational data, quality systems and production analytics.
- **Dell APEX (as-a-service infrastructure):** Consumption-based infrastructure that allows manufacturers to modernize incrementally while aligning investment with operational needs.

Ideally, a factory's modernization will build data security and resilience into the facility's operational architecture. For example, rather than adding controls after systems are in place, IT teams can enact OT/IT data safeguards that can keep cyberthreats at bay and, if intrusions occur, contain and address them quickly. For a facility's physical operations, engineers can design environments that simplify recovery and maintain continuity when disruptions occur.

Modernization should also dramatically improve a facility's manageability, reducing manual equipment operation, data collection and issue interventions that frequently require specialized expertise. Scalable, integrated technology solutions can lower the effort required to deploy updates, introduce new capabilities or extend successful practices to other production lines or plant sites.

Applying analytics and AI for practical, measurable value

Interest in AI and analytics continues to grow among manufacturers, driven by the same outcomes discussed earlier in this paper: more predictable operations, improved quality and lower operating costs. So far, adoption remains limited due to the need for specialized skills for application design, engineering and implementation and to avoid unnecessary disruptions during deployments.

In practice, these capabilities are most effective when they support existing maintenance, inspection and production workflows — helping teams make better decisions while working alongside AI-enabled systems and collaborative automation, including robotics, on the factory floor.

Monitoring in real time. Predictive maintenance (PdM) is one of the clearest examples. By analyzing equipment condition and performance data in real time and close to production, manufacturers can identify early signs of failure and plan maintenance more effectively.

Applied AI and analytics for manufacturing operations

Analytics and AI platforms support monitoring, pattern detection and operational insight across production environments. When integrated with core systems and data security controls, these capabilities help manufacturers improve maintenance, quality, energy use and planning without sacrificing transparency or control.

Hybrid approaches that span on-premises and cloud environments allow manufacturers to scale analytics and AI cost-effectively as needs evolve. Intel-powered Dell solutions, integrated with Windows and Microsoft Azure, support this flexibility across edge, plant, and cloud environments.

- **Dell AI Factory:** Providing an integrated portfolio of infrastructure, software, and services supporting governed AI workloads. Built on Intel® Xeon® processors and Intel® Gaudi® AI accelerators, Dell AI Factory enables factories to deploy AI-driven use cases such as vision-based quality inspection and predictive maintenance with high performance and scalability — without disrupting production.
- **Dell PowerEdge with accelerated compute:** Supporting predictive maintenance, quality analytics and operational monitoring.
- **Hybrid AI architectures:** Enabling analytics across entire production environments, from the floor to the edge to the cloud.

Industry studies indicate that PdM programs can reduce unplanned downtime by up to 50%,[4] helping teams move from reactive troubleshooting responses to planned interventions without adding complexity to day-to-day operations. PdM can also save up to 25% in maintenance costs and improve OEE by 10–12%.[5]

What's more, by identifying abnormal equipment behavior earlier, these approaches also reduce exposure to unsafe operating conditions, supporting safer maintenance practices alongside improved reliability.

Improving inspections. Quality inspection follows a similar pattern. Vision-based analytics applied at inspection points help surface defects that are difficult to detect consistently through manual methods alone. Research shows that AI-enabled inspection systems can improve defect detection accuracy to more than 97% compared to 60–70% rates with manual inspections.[6] This can support more stable outputs and higher yields when deployed directly on the line.

What's more, vision-based quality control and inspection can be used to track defects that show up in product recalls faster, helping isolate batches of damaged goods reducing cost of recalls.

Energy optimization also benefits from continuous analysis. Manufacturing environments generate large volumes of data related to utilities, equipment utilization and process efficiency. When that data is analyzed on an ongoing basis, teams can identify waste and validate adjustments in real time. Studies suggest that AI-driven energy optimization can reduce energy consumption by 20–30%,[7] lowering operating costs and supporting sustainability goals without interrupting production schedules.

Simulating processes effectively. Digital twins extend these capabilities by providing a way to model and test changes before they are applied on the floor. Their effectiveness depends on timely, reliable operational data and sufficient local processing to support simulation and analysis.

In practice, much of this analysis now occurs at the edge, where modern industrial PCs and edge servers perform real-time inference on locally generated data, thereby reducing latency and enabling faster operational decisions.

Across these examples, practical deployments of AI and analytics deliver the most value when they are embedded into operational contexts, introduced incrementally and supported by systems that make data usable where work happens. For manufacturers, this approach helps integrate AI and analytics into existing workflows, improving production performance without disrupting operations.

Taken together, these applications support incremental gains across availability, performance and quality — factors that directly influence OEE — without requiring disruptive changes to production.

Easing operational burdens amid workforce constraints

Workforce dynamics are adding pressure across manufacturing operations. As experienced workers retire, many organizations are finding it difficult to replace both headcount and institutional knowledge at the pace required to sustain production.

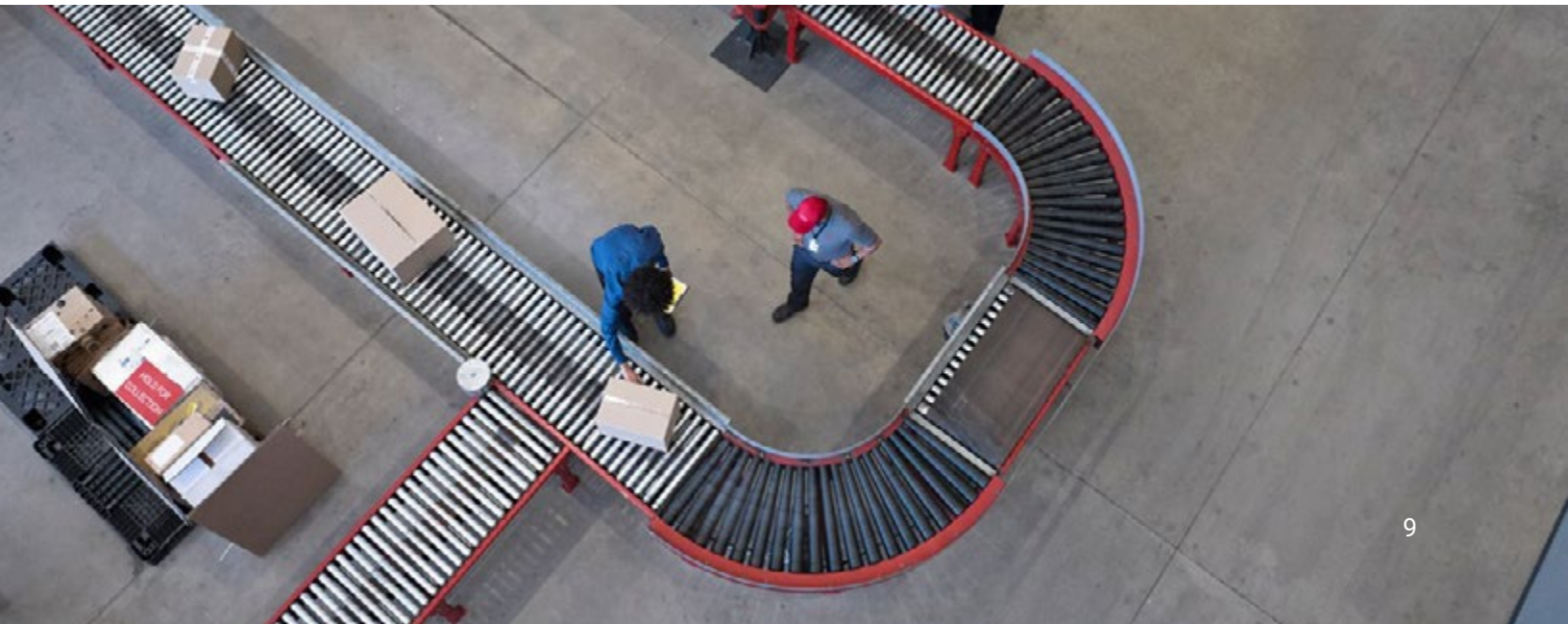
Twenty-six percent of the U.S. manufacturing workforce is age 55 or older, placing a significant portion of the industry's operational expertise near retirement.[8] At the same time, industry projections suggest manufacturers could face a shortfall of almost 2 million workers by 2030, driven by a combination of retirements, skills mismatches and competition for talent.[9]

Restoring know-how. These trends have practical consequences on the factory floor. Knowledge that once resided with long-tenured employees is harder to transfer, and newer workers are often expected to support increasingly complex systems with less on-the-job experience.

Surveys consistently show that a large majority of manufacturers report difficulty finding workers with the skills required to support modern operations, reinforcing the challenge of sustaining performance with limited staffing depth. In this environment, the ability to simplify operations becomes as important as adding capacity. Systems that improve visibility, standardize workflows and reduce reliance on manual intervention help offset workforce constraints.

Accessing data easily. When operational data is easier to access and interpret, teams can make decisions more confidently without depending on a limited number of specialists. Predictable, manageable environments also reduce the effort required to onboard new employees and support them effectively.

Over time, these capabilities help manufacturers maintain continuity as their workforce changes. By embedding knowledge into systems and supporting day-to-day decision-making with reliable data, organizations can perform more consistently despite ongoing labor challenges. In addition, as experienced workers retire, maintaining safe operating practices can become more challenging, increasing the value of integrated systems that flag safety risks as they occur so they can be addressed before an incident happens.



Integrated endpoints and workspaces for all personnel

From engineering and quality teams to maintenance and operations staff, manufacturers rely on secure, manageable endpoints to support daily decision-making. Aligning devices, identity, access controls and management tools help reduce operational friction and maintain consistency across roles and locations.

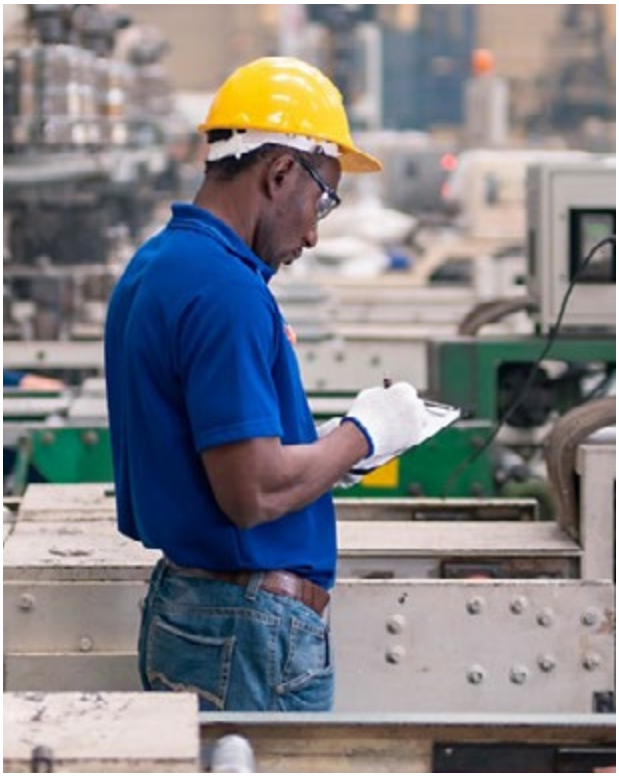
As endpoint environments extend into floor and edge locations, centralized orchestration and automation become essential to maintaining control at scale. With Windows 11 and Microsoft device-management software, these Dell endpoint solutions support deployment, data security and lifecycle management across manufacturing environments:

- **Dell Pro laptops and desktops:** Secure, manageable systems for operations, engineering and administrative staff. Dell endpoints built on the Intel® vPro® platform offer hardware-enhanced security and remote management, critical for protecting intellectual property and ensuring uptime in manufacturing environments.
- **Dell Pro Precision workstations:** High-performance systems for engineering, simulation, analytics and AI-assisted workflows at the point of work.
- **Dell Trusted Workspace and Management Solutions:** Centralized device deployment, security and lifecycle management.
- **Dell NativeEdge and Dell Automation Platform:** Orchestration and automation for deploying and managing endpoint and edge environments across manufacturing sites, supporting consistency, security and scale.
- **Dell thin client solutions:** Well-suited for control rooms, shared workstations and task-based production roles.

AI-capable, end-user devices at the point of work

AI-enabled PCs help bring analytics and intelligent assistance closer to manufacturing teams and data sources. By supporting local processing, these devices enable faster engineering and operational insights while maintaining data control and security.

- Dell Pro laptops and desktops: When paired with Intel-based AI acceleration and Windows 11 experiences such as Microsoft Copilot+, these systems support analytics, automation and productivity for manufacturing roles.
- Dell Pro Max laptops and desktops: Intel-powered, high-performance PCs designed for more demanding AI workloads, including data analysis, machine learning and simulation tasks.



Modernizing with confidence

For growing manufacturers, plant modernization is less about chasing the next trend and more about building confidence in how operations run every day and well into the future. The outcomes outlined in this paper — improved OEE, better quality products, lower operating costs and greater resilience — depend on making progress in ways that protect production rather than disrupt it.

Simplifying operations. That starts with choosing approaches that reduce complexity. When an integrated OT/IT foundation can work seamlessly across environments, manufacturers can gain much more real-time visibility into floor operations and equipment health as well as better control of systems behaviors over time. Analytics and AI can then become practical tools for improving decisions, rather than isolated experiments that struggle to scale.

This is where an integrated approach matters. Dell Technologies solutions, powered by Intel processors and running Microsoft Windows 11 and management tools, bring together infrastructure, edge capabilities, data platforms and data security to enhance manufacturing operations today and well into the future. With them, manufacturers can more easily connect systems, manage data closer to production and apply advanced capabilities incrementally — without increasing operational risk or management burdens.

Enriching worker roles. Just as important, this approach supports the people responsible for keeping production running. Simplified management, predictable performance and scalable designs allow teams to focus on improving operations instead of maintaining complexity.

Manufacturing environments will continue to face pressure from cost volatility, workforce constraints, sustainability expectations and evolving customer requirements. Organizations that build strong operational foundations today are better positioned to respond to those pressures tomorrow. With the right guidance and execution partner, manufacturers can move forward with confidence, strengthening performance now while creating a clear path for improvement.

Reducing unplanned downtime with predictive maintenance

Unplanned equipment failures remain one of the most direct threats to manufacturing performance. Reactive maintenance increases downtime, disrupts production schedules and raises the cost of labor and spare parts.

Predictive maintenance uses operational data from equipment, sensors and control systems to identify early signs of degradation. By analyzing patterns such as equipment vibration, motor amperage and temperature, and other operating parameters, maintenance technicians can anticipate failures before they occur and schedule mitigations during planned downtimes.

When predictive models run close to production, teams can gain timely insight without relying on constant connectivity or centralized processing. Maintenance becomes more targeted, asset life is extended and downtime reduced. This way, manufacturers can shift from reactive response to proactive planning, improving reliability without adding operational complexity.

Improving quality and yield through AI-based inspection

Maintaining consistent quality across production runs is difficult when inspection relies heavily on manual processes. Variability in lighting, speed and human judgment can allow defects to pass through undetected, increasing scrap, rework and downstream issues.

AI-based inspection applies computer vision and analytics directly on the production line to identify defects in real time. These systems analyze images and process data as products move through inspection points, flagging anomalies that are difficult to detect consistently through manual methods.

By operating at the edge, inspection systems support immediate response without slowing throughput. Over time, manufacturers gain more consistent quality, higher yield and clearer insight into the root causes of defects. The result is more stable production and reduced waste, achieved without disrupting existing workflows.

Lowering operating costs through energy optimization

Energy costs represent a significant and often under-managed component of manufacturing operations. Consumption patterns vary by equipment, process and shift, making inefficiencies difficult to identify through periodic analysis alone.

Energy optimization applies analytics to operational and utility data to monitor usage continuously and highlight opportunities for improvement. By correlating energy consumption with production activity, manufacturers can identify waste, adjust operating parameters and optimize equipment performance without interrupting output.

When these insights are generated close to production, teams can respond quickly and validate changes in real time. Over time, this approach helps reduce energy costs, improve efficiency and support more predictable operations while maintaining control over production schedules.

To learn more, visit Dell.com/Industries

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