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Flexible final assembly: How lineside automation enables the universal factory

A comprehensive analysis of automation technologies transforming automotive production

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Executive summary/abstract

> **92%** of manufacturers see smart manufacturing as the main competitiveness driver, up from 86% in 2019.
>
> *Deloitte*

The challenge of uncertainty

Automotive original equipment manufacturers (OEMs) face unique, global challenges as they navigate the complex production mix of electric vehicles (EVs), internal combustion engines (ICE) and hybrid powertrains. Modern production must accommodate massive variations in vehicle configurations, with trucks and large SUVs introducing hundreds of option packages, accessory combinations, and trim levels - each demanding unique assembly processes, parts sequencing, and material handling strategies.

Compounding these challenges are persistent labour shortages and growing worker ergonomic concerns. According to **Deloitte's 2025 Smart Manufacturing Survey**, 48% of manufacturers report moderate to significant challenges in filling production and operations management roles, while 92% now view smart manufacturing as the primary driver of competitiveness over the next three years. Traditional rigid, dedicated assembly lines can no longer meet these demands.

The solution lies in flexible, variant-ready architecture supported by advanced lineside automation. This whitepaper explores how innovations such as autonomous mobile robots (AMRs), modular assembly systems, and Industry 4.0 tools enable the universal factory concept, drawing on insights from industry leaders including **JR Automation**. By enhancing efficiency, flexibility, and safety, these technologies empower OEMs and tier suppliers to meet evolving market demands.

The manufacturing challenge

Deloitte's 2025 smart manufacturing survey

48%

Workforce challenge
Report moderate to significant challenges filling production and operations roles

92%

Competitive Priority
View smart manufacturing as primary driver of competitiveness (next 3 years)

Universal assembly lines

Defining universal production

With demand for pure EVs increasing at **rates far more tempered** than originally expected, the ability to produce multiple vehicle formats on the same line has proven critical. The term "universal assembly line" describes production systems capable of building ICE, hybrid, and fully electric vehicles on the same line without costly retooling or extended downtime. However, drivetrain variation is only one dimension of the flexibility required in modern automotive manufacturing. Vehicle platforms today must accommodate a wide range of configurations, from trim levels and cab designs to accessory packages and drivetrain options.

Consider the complexity of large SUVs and modern trucks: a single vehicle platform may offer dozens of trim levels, multiple bed lengths, various cab configurations, and hundreds of accessory packages. Each combination demands different parts, assembly sequences, and material staging strategies. Universal production systems address this complexity by standardising station architecture and integrating advanced automation technologies.

Engineering principles of universal lines

True universal production depends on several foundational engineering principles:

Standardised station architecture: Production stations feature modular, reconfigurable layouts that accommodate multiple vehicle types, often relying on Automated Guided Vehicles (AGVs) instead of fixed conveyors for flexible routing. For instance, Honda's **EV Hub in Ohio** employs a 'monument structure' consistent across ICE, hybrid, and EV variants. Conversely, the Porsche Taycan production at **the Zuffenhausen plant** uses a "Flexi-Line" concept with AGVs that route vehicles between standardised main assembly points and specialised "islands" for variant-specific tasks, dynamically optimising floor space utilisation by branching processes only when necessary.

Flexible end-effectors and tooling: Robotic systems use quick-change tooling and adaptive grippers for varied components and weights. Historically used for multi-model lines, this approach is now transformed to handle the specific demands of electrification. **BMW's Munich iFactory** uses advanced AI robotics to manage heavy battery packs and diverse componentry across varied production scenarios, preparing the site for fully electric Neue Klasse models.

Variant-aware automation: Vision systems, virtual tags and manufacturing execution systems (MES) enable automated systems to recognise specific vehicle configurations and adjust assembly parameters in real time.

Integrated offline kitting and material staging: Rather than presenting all possible parts at every station, systems integrate offline kitting with control systems to ensure the correct components arrive precisely when needed, reducing line-side inventory and eliminating picking errors.

The business case for universal production

The strategic value of universal production extends beyond technical capability. Universal production systems offer significant strategic advantages. By consolidating multiple vehicle types onto a single line, OEMs can reduce capital expenditure and respond more effectively to fluctuating EV adoption rates. Additionally, universal lines enable faster model refreshes and the introduction of new option packages without requiring extensive line rebuilds or production interruptions. As the industry continues to evolve, the ability to adapt quickly and cost-effectively will be a critical competitive advantage.

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Flexible, Modular EV + ICE Final Assembly

20 second cycle processes transfer cases across centre distances from 204mm to 319mm with minimal retooling.

JR Automation's Transfer Case Assembly System

Modularity in practise

Modular assembly architecture represents a fundamental shift from traditional linear production. Rather than designing each station for a specific vehicle model, engineers create standardised patterns around repeatable operations: fastening, insertion, seating, dashboard installation, and chassis-to-body marriage. This approach allows production lines to adapt to varying vehicle configurations without major disruptions.

For example, **Honda's modular production facilities** at the Marysville Auto Plant employ 75 modular production cells arranged in a flexible accordion-like layout. This design enables the plant to expand or contract operations as needed, accommodating ICE, hybrid, and EV production on a single line. The reconfiguration has also improved worker ergonomics and streamlined parts delivery, demonstrating the practical benefits of modularity.

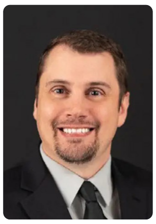
The automation systems that support these modular lines must be equally flexible. As Keith Ruck, Applications Engineering Manager at JR Automation explains: "When we receive a production schedule, that schedule often includes a mix of different models, variants and options, including both ICE and EVs, all running down the same main line. The automation feeding that line must therefore be highly flexible." By interfacing with sequencing systems that provide production schedules, automation can align inventory requests precisely with production, generating targeted replenishment requests and coordinating material delivery with specific vehicle variants as they arrive at the assembly line. This level of integration transforms flexible hardware into truly adaptive production systems.

The automation leader's **Transfer Case Assembly System** further exemplifies this modular, reconfigurable approach. The turnkey system assembles seven different models of transmissions with equipment logically arranged for future flexibility. Each station can be easily modified, re-tooled, re-programmed, or even re-used on different lines. The system processes transfer cases with centre distances ranging from 204mm to 319mm with a size envelope as large as 600 x 300mm, establishing a work envelope capable of handling substantial variant ranges with minimal retooling on a 20-second floor-to-floor cycle. This design philosophy - building flexibility into the fundamental station architecture - enables manufacturers to accommodate product changes without interrupting production schedules, embodying the modular principles essential to universal production.

Hybrid configurations: Robotics and manual assistance

In final assembly, the complexity and variability of tasks often exceed the capabilities of fully automated solutions. Hybrid configurations, which combine robotics with manual assistance, offer a practical solution. Industrial or collaborative robots (cobots) handle physically demanding tasks, such as lifting heavy battery modules or applying precise amounts of adhesive, while human operators manage dexterous operations requiring judgment and adaptability. For instance, at Audi's Ingolstadt plant, cobots work alongside employees to lift and position components, reducing repetitive strain and improving overall efficiency.

JR Automation has implemented similar human-robot collaboration systems across multiple applications. In one sunroof assembly application, robots present themselves to operators behind safety guarding, effectively becoming load fixtures. Operators load components that will ultimately be installed into the headliner, while robots simultaneously apply adhesive and place components. This approach exemplifies how collaborative systems can handle the complexity of variant-rich assembly while maintaining both productivity and worker safety.



"When employees are required to perform repetitive, dangerous or physically demanding tasks, retention tends to decline.

Keith Ruck, Application Engineering Manager

Keith Ruck emphasises the importance of this approach: "When employees are required to perform repetitive, dangerous or physically demanding tasks, retention tends to decline. By automating those repetitive, dangerous and arduous tasks, manufacturers can improve job satisfaction, reduce injury risk and ultimately improve employee retention."

Collaborative robots are scaling to enable flexible, mixed-powertrain assembly

Global collaborative robot market analysis & forecast: 2025-2032

2025 **$5.4 billion**

Market size

2032 **$64 billion**

Projected market

70% commonality will exist between Mercedes-Benz' VAN.EA and VAN.CA components, with both architectures produced on a single line from 2026.

Managing drivetrain and option variability

While EV battery pack installation and ICE engine marriage represent the most visible differences between powertrains, both can be accommodated with similar automation footprints when designed with flexibility in mind. **Mercedes-Benz's flexible van architecture** exemplifies this approach. Starting in 2026, the Van Electric Architecture (VAN.EA) and Van Combustion Architecture (VAN.CA) will share approximately 70% of common parts and be produced on the same line.

EV-specific modules, such as battery packs, require particular attention to lifting capacity and precision. Automated robotics and vision-guided positioning systems ensure accurate installation without disrupting overall line flow. At Honda's Marysville facility, for example, EVs receive their battery packs in a dedicated installation area, while ICE and hybrid vehicles pass through without stopping.

JR Automation's experience with battery handling demonstrates the critical safety advantages of automation in EV assembly. As Ruck explains: "Battery packs are extremely heavy and have relatively low storage density. Depending on the size of the pack, it may only be possible to fit one or two packs into a layer of dunnage. Storing these packs lineside consumes a significant amount of floorspace, so keeping them away from the main line is a major advantage."

The company's battery marriage operations utilise AMRs with lifting capability that allow battery packs to be loaded elsewhere, transported to the line, synchronised with line speed, and precisely aligned with the vehicle - addressing the challenge of handling heavy systems manually in confined spaces while improving both safety and efficiency.

Beyond powertrains, accessory-heavy trucks and SUVs introduce significant complexity. Vision systems guide automated robots through varying installation sequences, identifying specific component orientations and locations. Advanced vision technologies distinguish between hundreds of internal and external option packages, automatically adjusting programmed paths and material staging based on the specific vehicle configuration detected at each station.

JR Automation has deployed specialised vision-guided systems that excel in high-variability assembly environments. Their glass automation systems, for instance, use advanced vision to ensure glass panels are aligned accurately within vehicle openings, creating uniform gaps around the entire perimeter. The company also deploys stereo AI vision for bin-picking applications, enabling robots to identify and handle parts from randomly oriented dunnage - a capability particularly valuable when managing the diverse component variants required in modern vehicle production. These vision-guided solutions extend to stamping operations, where robots locate components on conveyor belts and place them into outgoing dunnage for downstream processes, demonstrating the versatility of adaptive vision systems across multiple assembly stages.

Lineside logistics: AMRs and AGVs for adaptive material flow

Addressing core logistics challenges

Traditional material handling in automotive assembly relies heavily on fixed conveyance systems, manual tugger trains, and static line-side presentation. While these methods have supported high-volume production for decades, they introduce significant challenges in today's high-mix, low-volume environments. Fixed systems consume valuable floor space, limit flexibility for line rebalancing, and create congestion during peak operations. Additionally, manual parts delivery often results in inconsistent timing and accuracy, particularly when managing the diverse parts mix required for highly customised vehicles.

Floor-space constraints:
Fixed conveyors and dedicated material staging areas consume significant production floor space, limiting flexibility for line rebalancing or capacity expansion.

Congestion and routing inflexibility:
Traditional conveyance creates fixed traffic patterns that can lead to congestion during shift changes or when accommodating special variants.

Inconsistent delivery timing:
Manual parts delivery introduces variability in timing and accuracy, particularly when handling the diverse parts mix required for high-option vehicles.

High variability in parts per build:
Different vehicle configurations require dramatically different parts counts - a base model pickup truck versus a fully loaded variant may differ by hundreds of components.

Advanced implementations of autonomous transport

Autonomous guided vehicles (AGVs) and autonomous mobile robots (AMRs) have evolved far beyond simple point-to-point material transport. Modern implementations demonstrate sophisticated integration with manufacturing execution systems and production control networks:

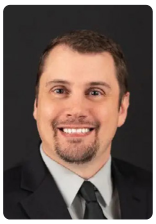
Mainline subassembly transport:
AMRs move major subassemblies - engine cradles, dashboard modules, battery packs - directly to the main assembly line, synchronised with production schedules. At **Stellantis' Sterling Heights Assembly Plant** in Michigan, the OEM deployed autonomous wheels retrofitted to standard carts and dollies for RAM pickup truck production.

Flexible production spurs:
Rather than dedicating fixed line positions to low-volume variants, AGVs create temporary assembly spurs, allowing special configurations to be completed offline while maintaining mainline throughput.

Dynamic rework routing:
When quality issues are detected, AGVs can automatically route vehicles to dedicated rework stations without stopping the main line, preserving takt time and minimising disruption.

Vision-aided docking and sequence validation:
Machine vision systems enable precise AGV docking at line-side positions and verify correct part sequences before delivery. **Ford's implementation** of AGVs at the Rouge Electric Vehicle Centre allows flexible line expansion without tearing up the floor to install fixed conveyance systems.

Offline kitting integration:
AGVs work in concert with offline kitting areas, collecting pre-assembled parts kits and delivering them to specific line positions based on real-time build schedules and variant requirements.



"One of the key advantages [of AVG & AMR implementation] is the ability to centralise material flow.

Keith Ruck, Application Engineering Manager

JR Automation's implementation of AGV and AMR systems demonstrates the practical benefits of centralising material flow. As Keith Ruck explains: "One of the key advantages is the ability to centralise material flow. When it comes to material storage, manufacturers can place manpower and materials close to receiving docks or truck stops, isolating and concentrating inbound logistics into a single area where people are already working." This approach eliminates the need to reserve valuable floorspace within the main line footprint for material storage, particularly important when multiple variants must be accommodated. The company's systems interface directly with plant MES and scheduling systems, enabling sequencing of material in the exact order required for production - creating what Ruck describes as "a highly coordinated process, effectively a miniature just-in-time delivery system within the factory floor."

A particular challenge in mixed AGV environments is coordinating multiple fleet managers from different suppliers. JR Automation's sister company, Flexware Innovation, has developed an AGV orchestration platform called Lift that functions as middleware between ERP, WMS, WCS, manual forklifts, and multiple AGV fleets. As Glen Guernsey, Chief Engineer for Warehouse Automation at JR Automation, notes: "One of the challenges in mixed environments is that different AGV suppliers each have their own fleet managers, and these systems do not communicate with one another. This can lead to situations where two AGVs occupy the same space and effectively block each other until a human intervenes." The Lift platform acts as a traffic controller, anticipating potential conflicts, assigning priorities, and rerouting vehicles as needed - ensuring smooth operation across all systems.

30%

faster in-plant material flow is enabled by BMW's cloud traffic-control system at Regensburg, coordinating over 500 AGVs with 100-millisecond position and battery-health updates.

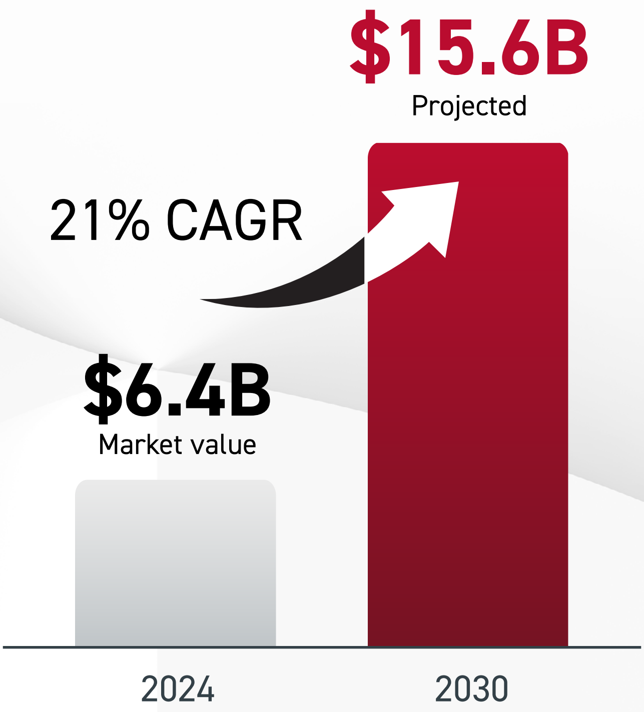
The strategic value of dynamic routing

The flexibility enabled by AGV and AMR systems extends beyond efficiency gains. **BMW's cloud traffic-control system** managing more than 500 AGVs at Regensburg, publishing position and battery-health data every 100 milliseconds, has reduced in-plant material lead-time by up to 30%. This proves particularly valuable when introducing new option packages or limited-edition models that would otherwise require dedicated line time or extensive changeover procedures.

Moreover, automated material handling supports universal line architecture by ensuring the correct parts arrive at the correct time for each specific vehicle configuration. As vehicles become more customised and option proliferation continues, this level of precision in material delivery becomes not merely advantageous but essential.

AGV/AMR market growth in automotive manufacturing

Global AGV/AMR Market Size



AGV Network (2025) - Interact Analysis Report

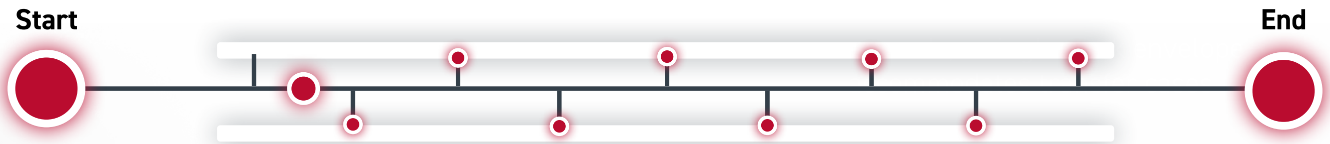
Body → Trim → Chassis Flow: Reimagined

Limitations of traditional sequential flow

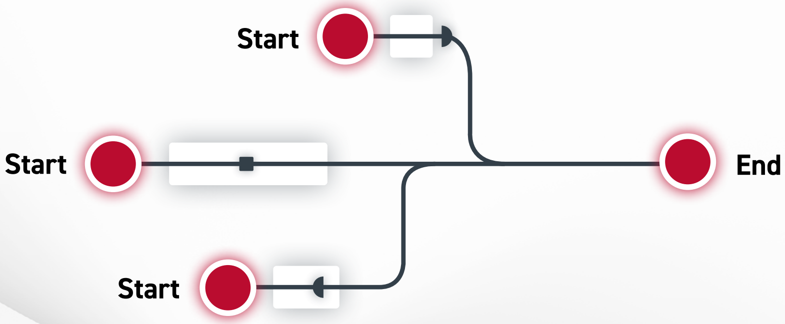
The classical automotive assembly sequence - body shop, paint shop, trim line, chassis marriage - has served the industry for decades. However, this linear progression creates inherent inflexibility. Fixed conveyor layouts dictate vehicle routing, making it difficult to accommodate varying assembly labour requirements or to bypass stations irrelevant to specific configurations.

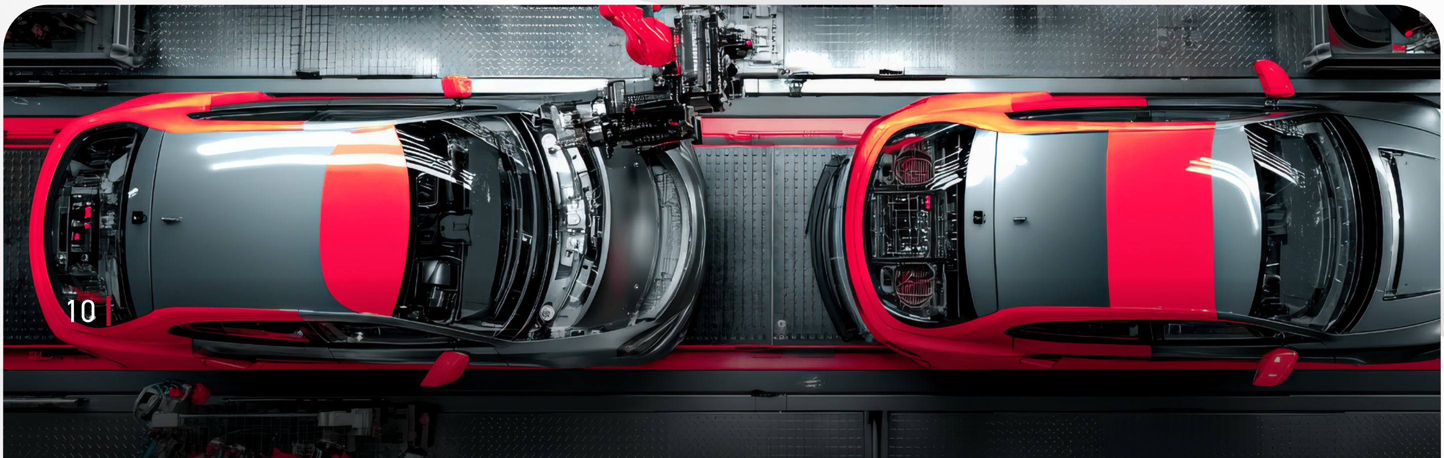
Heavy dependence on fixed conveyance also complicates line rebalancing. As vehicle mix shifts - for instance, when a plant increases EV production relative to ICE - the labour requirements at different stations change dramatically. Battery pack installation requires different timing and ergonomics than engine marriage; interior trim work differs substantially between base and luxury variants.

Assembly line



Ford universal EV production system



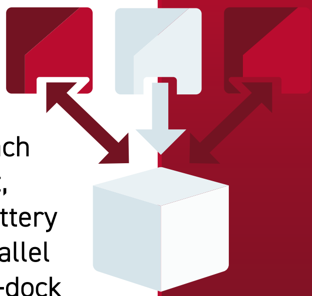


Next-generation flexible flow architecture

Modern flexible flow systems address these limitations through several key innovations. **Ford's Universal EV Production System** exemplifies this approach with its 'assembly tree' layout, where front, rear, and middle sections (including the battery as a structural component) are built in parallel and then joined together, reducing dock-to-dock workstations by 40%.

Production stations increasingly feature adaptive capabilities, allowing them to handle both EV and ICE tasks with minimal changeover. Advanced welding robots at **Honda's retooled facilities** can now weld both EV and ICE bodies on the same line, while dedicated areas allow battery pack installation for EVs as ICE and hybrid vehicles pass through without stopping.

Variant-driven takt time balancing represents another critical evolution. Traditional fixed takt assumes similar labour requirements across all vehicles, but trucks and large SUVs introduce massive deviations. AI-powered vision systems and dynamic material staging help balance this workload by adjusting buffer sizes, activating additional work cells, or redistributing tasks across parallel stations.

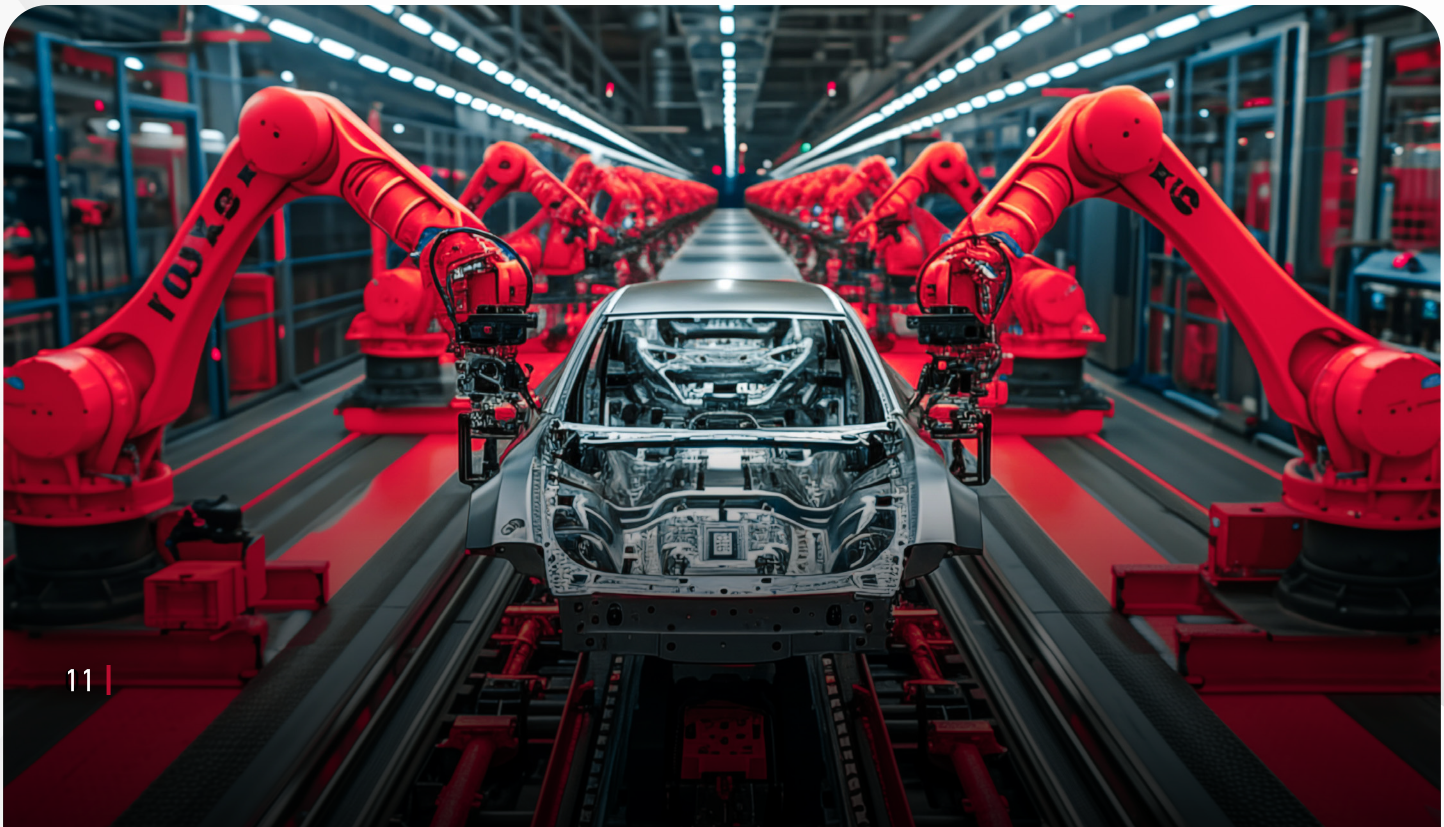


40%

fewer dock-to-dock workstations enabled by Ford's assembly-tree EV production model with parallel sub-assembly integration.

Rework and quality management

Perhaps most significantly, flexible flow architecture fundamentally changes how plants handle quality issues. Rather than stopping the mainline, vehicles requiring rework can be automatically routed to dedicated spur stations, where technicians address problems without impacting overall throughput. This capability has proven particularly valuable as vehicles become more complex.



Smart tooling and operator ergonomics

The evolution of assembly tooling

Smart tooling represents a critical enabling technology for flexible final assembly. Digital torque tools with real-time verification connect directly to manufacturing execution systems, automatically adjusting parameters based on the specific vehicle configuration at each station. These tools not only ensure consistent quality but also provide immediate feedback when torque specifications fall outside acceptable ranges.

Advanced guidance systems further enhance operator capability. At **BMW's Regensburg facility,** augmented reality (AR) glasses provide step-by-step guidance for complex assemblies, while immersive digital twins allow workers to experience new workflows years ahead of production start. The plant produces a new vehicle every 57 seconds, each configured uniquely, demonstrating the effectiveness of these systems.

Variant-aware tooling takes this concept further. By integrating with vehicle identification systems, smart tools can automatically load the correct torque specifications, fastening patterns, and quality checkpoints based on the specific vehicle entering each station.

Real-time locating systems (RTLS) enhance this capability by tracking portable tooling throughout the assembly area. Tags mounted to tools monitor their position, enabling the tooling only when located in areas where usage is expected. This location-based approach allows parameters to be loaded automatically based on both the vehicle variant and the station location, while quality information is tracked directly to the precise point of work - creating a comprehensive digital record that links each assembly operation to its exact location and the specific vehicle being built.

Automotive manufacturing workflow

01
Data capture
Real-time variant identification via RFID/barcode scanning

02
Digital matching
Instant configuration lookup and tool parameter retrieval

03
Auto adjustment
Servo-driven tooling reconfigures in milliseconds

04
Quality Verification
Vision systems confirm correct tooling setup

Ergonomics in the age of electrification

The transition to EVs introduces new ergonomic challenges. Battery modules are often heavier and more awkwardly shaped than traditional engine components. **Ford's ergonomics program** has documented significant improvements through systematic application of virtual simulation and motion capture, with every workstation at the Rouge Electric Vehicle Centre designed with the operator in mind.

Trucks and large vehicles compound these challenges. Assembly work often requires elevated positions, overhead installations, or deep-cabin access. Assist robotics and collaborative systems address these challenges by handling the heavy lifting while operators guide final placement. At Audi's Ingolstadt plant, collaborative robots work directly alongside employees, taking components from material boxes and passing them to workers, eliminating repetitive motions.

Vision-guided systems play a crucial role in maintaining ergonomics while accommodating variability. By precisely identifying component orientation and optimal installation approaches, these systems guide operators through the least strenuous installation method for each specific configuration.

Reducing changeover time through automation

30% faster in-plant material flow is enabled by BMW's cloud traffic-control system at Regensburg, coordinating over 500 AGVs with 100-millisecond position and battery-health updates.

The business impact of changeover

Changeover time represents one of the most significant sources of production inefficiency in automotive assembly. **At Ford's Dearborn Truck Plant**, where an F-150 derivative rolls off the line every 53 seconds with hundreds of possible configurations, even 15 minutes of unplanned downtime can cost tens of thousands of dollars in lost production.

The complexity of modern vehicles exacerbates this challenge. A model year update might involve hundreds of new part numbers, revised fastening sequences, and modified quality checkpoints. Without automation, operators must consult documentation, introducing delays and potential errors.

Automated changeover solutions

Vision-based model and variant recognition systems eliminate manual identification steps. As each vehicle enters a station, cameras and sensors automatically detect its configuration, triggering the appropriate assembly program without operator intervention. Modern systems can reliably distinguish between hundreds of variants in milliseconds.

Programmatic recipe changes in programmable logic controllers (PLCs) and robot controllers enable instant adjustments. Rather than manually reprogramming stations, engineers create libraries of assembly Programmes that activate automatically based on vehicle identification data. Quick-swap tooling mechanisms, featuring standardised interfaces and automated changeover procedures, further reduce transition time.

Automated materials verification provides additional time savings and quality assurance. Systems scan incoming components, verify they match the build requirements, and alert operators immediately if discrepancies are detected, preventing costly part mismatches.

Measurable benefits

The cumulative effect translates to substantial operational advantages: faster changeovers enable more frequent mix adjustments; reduced downtime directly improves equipment effectiveness; greater responsiveness allows build-to-order rather than build-to-forecast production; and better takt-time consistency improves predictability.

Digital twins and AI for high-mix final assembly

Digital twins: Reducing risk in complex deployments

Digital twin technology has evolved from conceptual visualisation to practical production tool. **BMW's application of digital twins** exemplifies mature implementation across multiple dimensions. The company has scanned all plants in its network using NVIDIA Omniverse Enterprise to create accurate spatial models that serve as a foundation for system planning - allowing proposed equipment updates to be overlayed and reviewed for physical fit and spatial interaction with existing infrastructure before implementation.

Beyond these spatial models, BMW maintains true digital twins built in software environments that enable dynamic simulation of production system behaviour. As **the OEM's Munich plant director notes**, this virtual-first mindset has transformed equipment upgrades: changes to welding robots or structural components that once required production halts can now be planned and validated virtually. AI-driven measuring systems record live data, feed it into the cloud, and automatically update robot programming in real time - keeping the digital twin synchronised with actual production conditions and enabling simulation of moving interactions, cycle times, and process flows before physical changes occur.

"We follow a highly structured project execution process across all divisions of the organisation.

Glen Guernsey, Chief Engineer

Critically, digital twins in automotive assembly must validate more than single-vehicle scenarios. They must test different drivetrain combinations, various option packages, and the transitions between different vehicle configurations. While this comprehensive validation may not dramatically reduce initial commissioning time, its true value lies in risk mitigation. By identifying design flaws, collision scenarios, or unsafe operating conditions in the virtual environment, digital twins prevent errors that could cause significant production delays, require costly system rework, or create dangerous situations that might go unnoticed until personnel or equipment are at risk. In complex, high-mix assembly environments where hundreds of variant combinations must be accommodated, this preventative validation becomes essential.

Translating virtual validation into production-ready systems requires equally disciplined physical implementation processes. JR Automation's structured project execution process exemplifies this integration. As Glen Guernsey explains: "We follow a highly structured project execution process across all divisions of the organisation. This process includes defined tollgates, such as the concept phase, design phase, build phase and delivery phase. At each of these phases, there is a formal buy-in point with the customer to ensure alignment. In the concept and design phases in particular, safety is a critical focus."

The company applies stringent safety assessments across all relevant disciplines, considering operator interaction, maintainability, and long-term system performance. This disciplined approach to design validation and safety assessment - built into formal project phases - complements the virtual validation capabilities of digital twins, ensuring that automated systems are safe, reliable, and ready for production from day one.

AI applications in robotics and controls

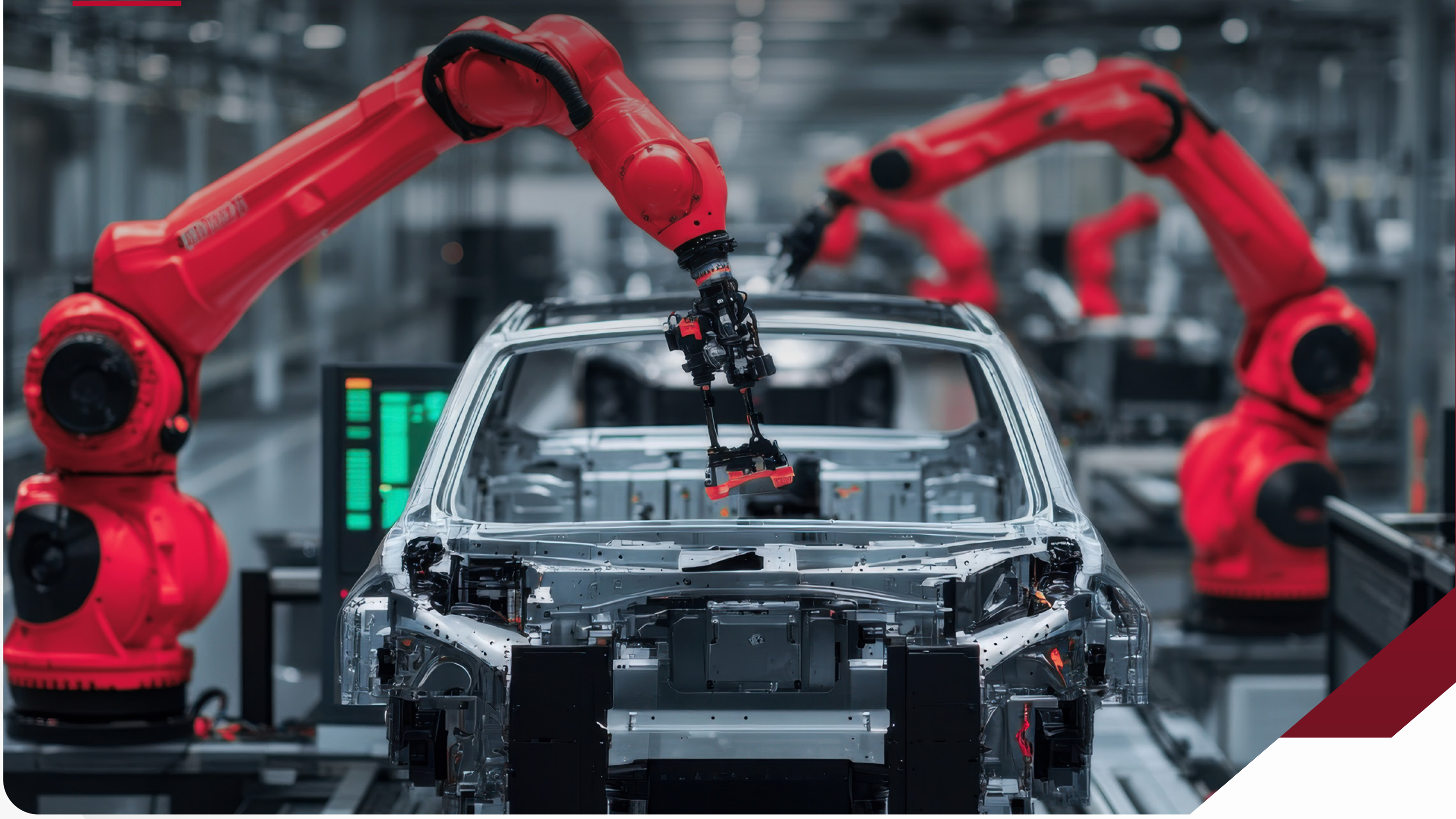
Artificial intelligence applications in final assembly focus primarily on areas where variability exceeds the capabilities of traditional fixed programming. AI-driven robot guidance enables systems to handle complex part handling where component orientation varies or where tolerances are tight.

Adaptive path planning becomes essential in high-mix assembly. **BMW's GenAI4Q system at Regensburg** demonstrates practical AI application: the system analyses vehicle specifications, real-time production data, and factory conditions to create bespoke inspection checklists for each of the approximately 1,400 cars assembled daily.

Predictive bottleneck detection represents a more recent AI application. By analysing real-time production data, AI systems can identify emerging bottlenecks before they impact throughput. **Deloitte's 2025 Smart Manufacturing Survey** found that 29% of manufacturers now use AI or machine learning at the facility or network level, with 78% allocating more than 20% of their improvement budgets to smart manufacturing initiatives.

The key distinction in successful AI deployment lies in focusing on practical, measurable applications. The most effective implementations target specific pain points - variable part handling, complex assembly verification, or dynamic scheduling - where AI's pattern recognition and adaptive capabilities provide clear advantages.

Driving the future: Embracing flexibility and resilience in automotive production



From flexible systems to competitive resilience

The universal, flexible assembly line is no longer an aspirational concept but an operational imperative in automotive production. As the industry navigates the uncertain transition to electrification while accommodating unprecedented levels of vehicle customisation, the ability to produce multiple powertrains and configurations on a single line has become essential for competitiveness.

The technologies enabling this transformation - universal station architecture, AMR-enabled intralogistics, modular automation cells, smart tooling, and AI-supported robotics - have matured from experimental deployments to production-proven solutions. Digital twins allow manufacturers to validate complex implementations before physical commissioning, reducing risk and accelerating deployment.

Looking forward, the competitive advantage will increasingly belong to manufacturers who can rapidly adjust production mix in response to market demand while maintaining quality, efficiency, and worker safety. The flexible factory is not merely about technological sophistication; it is about building resilience into the production system - the ability to absorb variability, respond to uncertainty, and capitalise on opportunities without massive capital redeployment.

For OEMs and tier suppliers evaluating their automation strategies, the question is no longer whether to pursue flexible, universal production capabilities, but how quickly they can implement them. The manufacturers who successfully deploy these technologies today will be positioned to lead the industry through whatever powertrain transitions, market shifts, and customisation demands emerge in the years ahead.

Universal, flexible assembly lines have evolved from aspiration to operational imperative - the ability to produce multiple powertrains and configurations on a single line is now essential for competitiveness.

Core enabling technologies - universal station architecture, AMR-enabled intralogistics, modular automation cells, smart tooling, and AI-supported robotics - have matured to production-proven solutions.

Competitive advantage belongs to manufacturers who can rapidly adjust production mix in response to market demand while maintaining quality, efficiency, and worker safety.

The critical question for OEMs and tier suppliers is no longer whether to pursue flexible production capabilities, but how quickly they can implement them.

Success requires building resilience into production systems - the ability to absorb variability, respond to uncertainty, and capitalise on opportunities without massive capital redeployment.

Leading solutions in lineside automation

The transformation to flexible final assembly requires partnerships with automation systems integrators who possess deep expertise in automotive manufacturing. These partners must demonstrate capabilities across robotics integration, AGV/AMR implementation, digital manufacturing systems, and safety compliance.

JR Automation, a Hitachi Group Company, exemplifies the integrated approach required for successful implementation., Their capabilities span the full spectrum of lineside automation technologies, including AGV and AMR integration with robust vertical integration into customer manufacturing execution systems, robotics integration incorporating machine vision for complex assembly tasks, and comprehensive safety assessments ensuring compliance with ANSI B56.5, RIA 15.08, and ISO 3691-4:2020 standards.

The company's experience with flexible welding cells for low-volume, high-mix production and automated assembly solutions that accommodate variant complexity demonstrates the practical application of the principles outlined in this whitepaper. Their approach emphasises not merely hardware delivery but complete manufacturing integration, combining automation, control systems, and information technology into cohesive production solutions.

As manufacturers evaluate automation partners, key considerations should include: proven experience with automotive final assembly applications, demonstrated capability to integrate diverse automation technologies into unified systems, robust safety engineering and risk assessment processes, ongoing service and support infrastructure, and the ability to scale solutions from individual cells to plant-wide implementations.

About this whitepaper

This whitepaper was produced by **Automotive Manufacturing Solutions (AMS)**, the leading global resource for automotive manufacturing professionals and suppliers. AMS provides in-depth coverage of production technologies, plant operations, and industry trends shaping the future of vehicle manufacturing.

Key sources

This analysis draws on extensive research including:

Porsche Taycan Flexi-Line production system at Zuffenhausen

Honda's EV Hub flexible manufacturing implementation

BMW Regensburg Factory of the Year recognition

Ford's Universal EV Production System

Modular manufacturing transformation analysis

Industry analysis of flexible assembly lines

S&P Global Automotive Supplier Outlook 2025

Deloitte 2025 Smart Manufacturing and Operations Survey

JR Automation Case Study: Transfer Case Assembly

For more information:

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