INNOVATION AT ALSTOM: SMART MANUFACTURING

ALSTOM
· mobility by nature ·

Innovation is developing and implementing new ideas, methods, or products that bring significant improvements or solve existing problems. In today's world, innovation is happening at an unprecedented pace in various fields, including material, technology, renewable energy, artificial intelligence, and processes, among others.
It is important to not only follow a long-term vision but also to make innovations quickly available. At Alstom, we, therefore, differentiate between "innovation in the now" and "innovation for the future".

"Innovation in the now" means to be focused on what is possible today, innovations that can be deployed right now or in a very short amount of time. "Innovation for the future" addresses longer-term trends expected to represent future and often complex challenges that need to be prepared in advance.
This paper is part of a series of documents that explain our approach to a specific topic to deliver innovation in the now and to prepare innovation for the future.

Combining new tools with expert knowledge

Smart manufacturing is a comprehensive approach that involves the integration of advanced technologies, sensors, and data analytics to optimize the manufacturing process, increase productivity, and reduce costs. Some key products and systems that belong to smart manufacturing include industrial internet of things (IIoT), machine learning and artificial intelligence (AI), digital twins, automation and robotics, and data analytics software.

Alstom designs and manufactures various types of trains, including high-speed trains, regional trains, metros, trams, and freight locomotives.

We provide well-advanced signalling and control systems for urban and mainline rail networks and a wide range of digital tools for monitoring, managing, and optimizing rail operations, enhancing safety, reliability, and efficiency. All these products and systems involve complex manufacturing processes that can be significantly enhanced through the utilization of smart manufacturing tools and techniques.

A prerequisite for success: Get the people involved and ready.

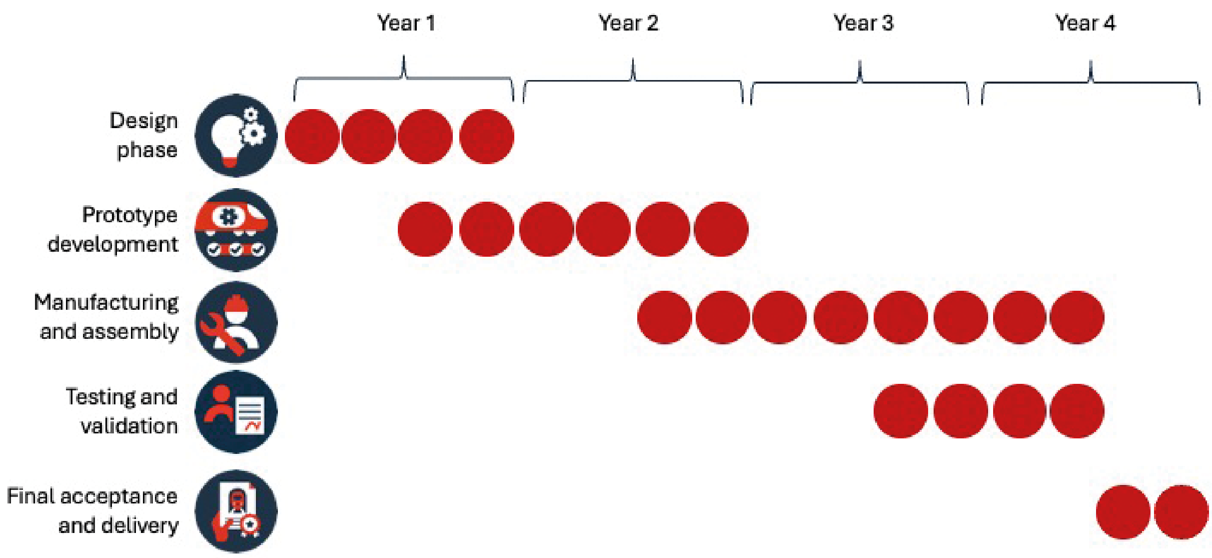
The transition to smart manufacturing brings about significant changes in processes and workflows. As smart manufacturing incorporates advanced technologies such as IoT, AI, and data analytics, employees require specialized training to effectively use these tools.

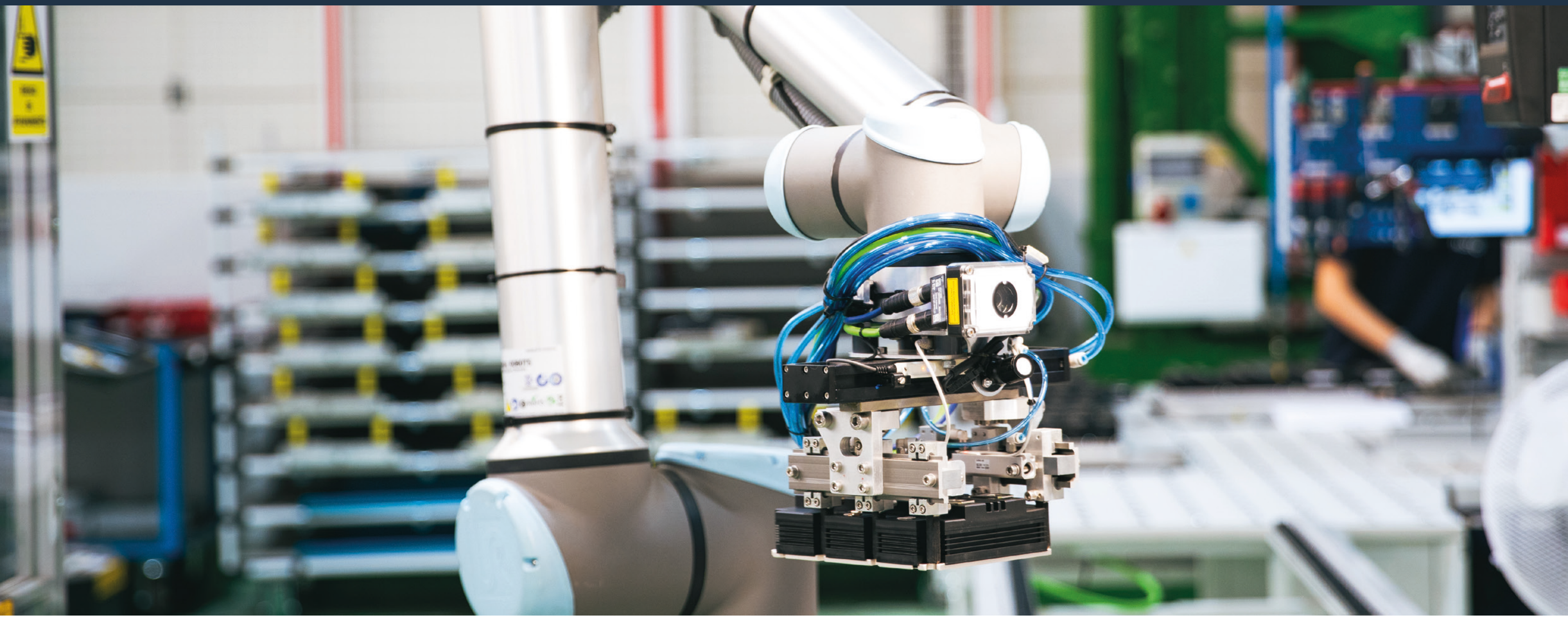
Comprehensive training programs play therefore a vital role in successfully implementing smart manufacturing initiatives. These programs empower employees to embrace new systems and methodologies, ensuring a smooth transition while also maximizing the return on investment.

At Alstom, we have successfully launched an internal academy composed of a series of mobile schools and digital training programs that offer customized training, for example on our specific welding robot applications and controller troubleshooting. These initiatives ensure that employees are well-prepared, competent, and actively engaged in the transformation towards more innovative and efficient manufacturing practices.

Speed matters

The time required to build a train or a safety system for rail can vary significantly based on factors such as the complexity of the system, the supply chain, and production capacity. Below is a general breakdown of the phases involved in building a regional train, along with estimated timeframes for each phase:





These estimates are general and may vary. Some projects may be expedited through advanced manufacturing techniques or by overlapping phases, while others may experience delays due to regulatory approvals or supply chain issues. Smart manufacturing techniques enhance collaboration, improve efficiency, and enable faster decision-making throughout the design and build phase for new train systems. By integrating advanced technologies and practices, manufacturers can significantly reduce lead times and improve overall project outcomes.

Smart manufacturing Innovation in the now and for the future

This document discusses innovation examples of smart manufacturing used at Alstom today. It also gives an outlook on selected future areas, where innovations allow to address the growing need for smart tools and technologies used in modern rail manufacturing.

Innovation in the now: Automation and robotics

In the railway sector, the implementation of automation extends far beyond merely acquiring robots for standardized processes and pressing a button. It necessitates a highly skilled project team composed of robotics experts and specialists in unique operational processes.

This team is essential for effectively managing suppliers throughout the entire project lifecycle, ensuring that the desired level of performance is achieved.

Although still relatively new, our automation program is becoming increasingly vital in enhancing execution efficiency and compliance for Alstom products. Through automation, we can significantly improve various key performance indicators such as quality, productivity, and competitiveness. Additionally, it contributes to increased capacity, reduced production lead times, and enhanced ergonomics on the ground. This is particularly beneficial for addressing repetitive and demanding tasks faced by operators.

Our commitment to innovation is exemplified by the successful deployment of the standardized process across 100% of new robotic projects. Alstom's manufacturing robots are primarily deployed for special processes such as welding and surface treatment but are also applicable to machining, cobots, and inspection. Currently, Alstom operates over 130 robots at approximately 30 sites worldwide, covering around 15 different applications, with welding representing 70% of its assets.

Innovation in the now: Industrial Internet of Things (IIoT)

The IIoT refers to the interconnected network of devices and sensors in industrial settings that collect and share data to improve operations, enhance efficiency, and enable predictive maintenance.

Alstom utilizes the IIoT in train system manufacturing by implementing real-time monitoring through sensors that track equipment performance and conditions on the production line, ensuring optimal operation. Predictive maintenance is also a key aspect, as machinery is continuously monitored for signs of wear or failure, allowing for timely maintenance before breakdowns occur.

Data analytics plays a crucial role in analysing production process data to identify inefficiencies and optimize workflows. Additionally, IIoT enhances supply chain integration by improving visibility and coordination among suppliers, which leads to better inventory management and reduced lead times. Finally, continuous monitoring facilitates the immediate detection of defects, ensuring adherence to high-quality standards. Overall, these applications contribute to increased efficiency, reduced costs, and higher-quality train system manufacturing at Alstom.

Innovation in the now: Advanced Manufacturing Processes

Advanced manufacturing processes encompass innovative techniques and technologies that enhance the efficiency, precision, and flexibility of production systems across various industries. By leveraging advanced tools, materials, and data analytics, these processes improve product quality, reduce lead times, and minimize waste. They enable companies to adapt to changing market demands and complex designs, ultimately driving competitiveness and sustainability.

At Alstom, two key examples of advanced manufacturing processes are additive manufacturing (3D printing) and lean manufacturing.

Additive manufacturing creates components layer by layer using materials like plastics and metals, allowing for rapid prototyping, customization, and the production of complex geometries. This approach significantly reduces lead times, eliminates minimum order quantities, as seen with a recent order of 40 curtain hooks, and minimizes inventory needs, enabling customers to adopt a 'digital warehouse' with 'on-demand spares'. Additionally, it promotes sustainability through reduced material waste and lower energy consumption.

Since 2016, Alstom has utilized 3D printing for various projects across multiple countries, operating 150 machines at established hubs and managing smaller print jobs in-house. The company also plans to introduce capabilities for extra-large prints using robotic technology, further expanding its manufacturing capabilities.

Lean Manufacturing focuses on eliminating waste and enhancing efficiency by streamlining workflows and optimizing resource utilization throughout the production process. At Alstom, lean principles are seamlessly integrated into the performance system, fostering a culture of efficiency across various domains, including project engineering and manufacturing. Alstom's annual improvement plan prioritizes quality to maintain a competitive edge, with the Alstom Performance SYStem (APSYS) community playing a crucial role in facilitating Lean implementation.

Launched in 2004, Alstom's APSYS production system is a vital tool for bolstering competitiveness. Inspired by lean principles, APSYS emphasizes standardization, problem-solving, and continuous improvement while prioritizing quality, cost reduction, timely delivery, and safety.

Key innovations include transitioning from a push to a pull flow system, which has resulted in a significant inventory reduction, alongside promoting flexible manufacturing processes.

The APSYS system nurtures ongoing improvement through user-friendly tools, comprehensive training, and practices like the Five Ss[1] for workstation maintenance, as well as autonomous team meetings for performance assessments. Additionally, APSYS conducts week-long SWIPs (Single Week Improvement Programme) to uncover efficiency opportunities, leading to significant gains in space utilization and time savings. With a robust framework of monthly self-assessments and regular audits, APSYS encompasses a wide range of product lines, ensuring consistent progress and enhancing the effectiveness of Alstom's manufacturing strategy.

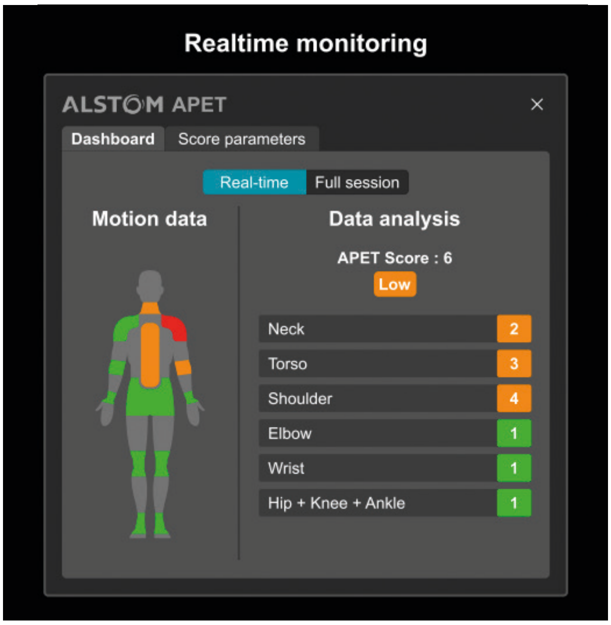
[1]The Five Ss are abbreviations for five Japanese terms: seiri (sorting), seiton (orderliness), seiso, (cleanliness), seiketsu (standardization) and shitsuke (maintaining).

Innovation for the future: Data science and ergonomics

Data science is set to revolutionize smart manufacturing by enhancing various processes within the industry. One significant area of application is ergonomics, where advanced algorithms analyse data to improve working conditions or other work processes. This chapter summarizes different initiatives that are under development at Alstom.

Alstom posture evaluation technique

Alstom is developing an in-house application that provides real-time posture evaluation through advanced full-body motion tracking technology, capturing and recording a person's movements in a virtual three-dimensional space. This digital tool monitors real-time body movements, allowing a 3D avatar to replicate the user's actions. Proactive ergonomic assessments utilize Virtual Reality (VR) technology, while reactive assessments are conducted using Augmented Reality (AR). The proactive approach includes a VR-based human motion tracking tool, which requires sensors placed on the arms, legs, and waist for accurate tracking. In contrast, the AR tool leverages AI-based image recognition to monitor joint angles and analyze motion thresholds. This algorithm generates an APET score and presents a comprehensive post-evaluation score for various body parts through an intuitive dashboard. By combining immersive technology with customizable assessment parameters, Alstom's posture evaluation technique significantly enhances decision-making for optimizing workplace safety and performance.



Ergonomic work cell

The ergonomic work cell offers customizable working zones tailored to manufacturing and product development needs, enabling design validation without physical prototypes.

Its structure includes fixed and adjustable arms, allowing users to quickly configure the setup to desired dimensions using a dial scale. By eliminating the costs and resource demands of traditional mock-ups, the ergonomic work cell provides a portable solution for rapidly creating physical environments, reducing the need for expert travel to inspect train or component manufacturing sites.

For process feasibility studies focused on reachability, accessibility, and operator ergonomics, we utilize motion-tracking sensors and a VR head-mounted display. This setup immerses users in a virtual shop floor experience, allowing for the assessment of assembly, serviceability, and depot operations. By combining virtual and real-time data, the ergonomic work cell enables comprehensive visibility and insights into the operator's experience.

Digital Human Twin

Alstom uses the ergonomic assessment tools CAPTIV and Ergolife to improve workplace safety and efficiency by focusing on human factors. These tools leverage advanced motion capture and analysis technology to evaluate workplace ergonomics, providing quantitative data on body posture and movement to identify ergonomic risks and enhance employee well-being. This measurement equipment facilitates the creation of a digital twin, offering valuable insights for operational models and various use cases. Both tools contribute to the field of ergonomics by utilizing data and technology to promote safer and more efficient workplaces.

Exoskeletons

Exoskeletons support workers by assisting specific body parts, such as the back, arms, or legs, during repetitive or physically demanding tasks. At Alstom, we use passive exoskeletons with mechanical components, such as springs, to improve workplace ergonomics and reduce the risk of musculoskeletal disorders. Before acquiring exoskeletons or other assistance devices, it is essential to conduct a thorough ergonomic analysis of the work environment. The effectiveness of exoskeletons depends on how well they match the work task conditions and the operator’s specific physical assistance needs. Advanced data models are used to ensure that the selected solution effectively addresses ergonomic challenges and enhances workplace safety.

Innovation for the future: Data analytics software

Data analytics software plays a crucial role in smart rail manufacturing by enhancing efficiency, improving safety, and optimizing processes. It is primarily used for predictive maintenance, where data from sensors on trains and tracks is analysed to predict equipment failures before they occur, minimizing downtime and reducing maintenance costs. Additionally, data analytics aids in operational optimization by streamlining production schedules, inventory management, and resource allocation, leading to a more efficient manufacturing process.

Quality control is another critical application, as real-time monitoring of production processes allows for the early identification of defects or deviations, enabling immediate corrective actions. Furthermore, advanced analytics assists in supply chain management by tracking and analysing performance, helping Alstom anticipate disruptions and improve logistics and supplier relationships.

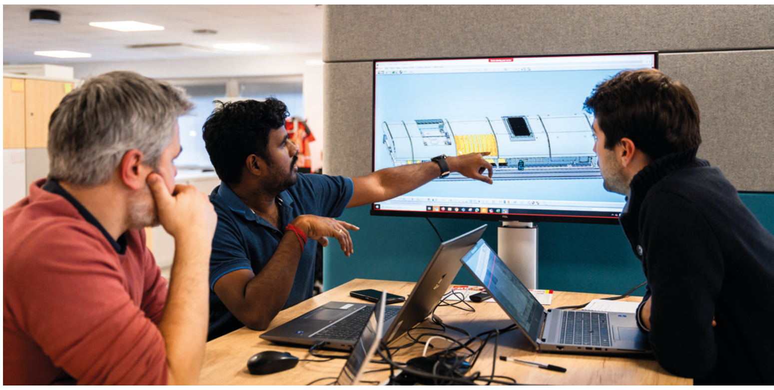
Performance analysis is enhanced through data analytics, providing valuable insights into operational trends that inform decision-making and encourage continuous improvement in manufacturing practices. Safety enhancements are achieved by analysing historical and real-time data, resulting in safer manufacturing environments and reducing risks associated with rail production.

Innovation for the future: Digital train twin

Initially, Alstom focused on creating digital twins for individual subsystems within the train, such as the propulsion system, braking system, doors, or pantographs. These digital twins are virtual representations that replicate the physical attributes and behaviours of these systems, enabling real-time monitoring, analysis, and simulation.

As Alstom advanced its digital capabilities, the next step was to integrate these individual digital twins into a cohesive framework. This integration allows for a comprehensive understanding of how the various subsystems interact with each other within the train environment, leading to improved system performance and reliability.

The use of data analytics and artificial intelligence plays a crucial role in this evolution. By analysing data from the digital subsystem twins, Alstom can gain insights into performance optimization, predictive maintenance, and operational efficiency. AI algorithms help in identifying patterns and anomalies, further enhancing the reliability of the entire system. The culmination of these efforts is the creation of a digital train twin, which encompasses the entire train’s lifecycle. This holistic digital representation includes not only the integrated subsystems, but also dynamic data related to the train’s performance, environmental conditions, and operational context.



The digital train twin allows the different actors along the value chain to

- **Understand** how the system operates with the given parameters and identify bottlenecks.
- **Explore** different ways to design, build, operate, and maintain trains more cost-effectively, in a fast and safe manner within a digital environment.
- **Compare** scenarios, assess KPIs, and make informed decisions.

Looking ahead, Alstom aims to continually enhance its digital twin technologies by incorporating advancements in IoT, machine learning, and big data analytics, further improving the performance and sustainability of its trains.

Transforming rail manufacturing through smart technologies

Smart manufacturing transforms traditional train system manufacturing by incorporating advanced technologies and processes at every stage. From the initial design and engineering phases to final quality assurance and testing, leveraging IoT, AI, additive manufacturing, and real-time data analytics creates a more efficient, reliable, and sustainable production environment. This results in higher quality train systems, faster production times, and significant cost savings, positioning manufacturers to meet the evolving demands of the rail industry.

Transforming train system manufacturing is however not only about technology. Change management and adapted training tools are essential building blocks for successfully implementing smart manufacturing methods, addressing challenges, and fostering a culture of innovation and continuous improvement. It ensures that organizations can effectively transition to advanced manufacturing technologies while maximizing the potential benefits.

Abbreviations

AI Artificial intelligence

APSYS Alstom Performance SYStem

AR Augmented Reality

IIoT Industrial internet of things

IoT Internet of things

ML Machine learning

SWIP Single week improvement programme

VR Virtual reality

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