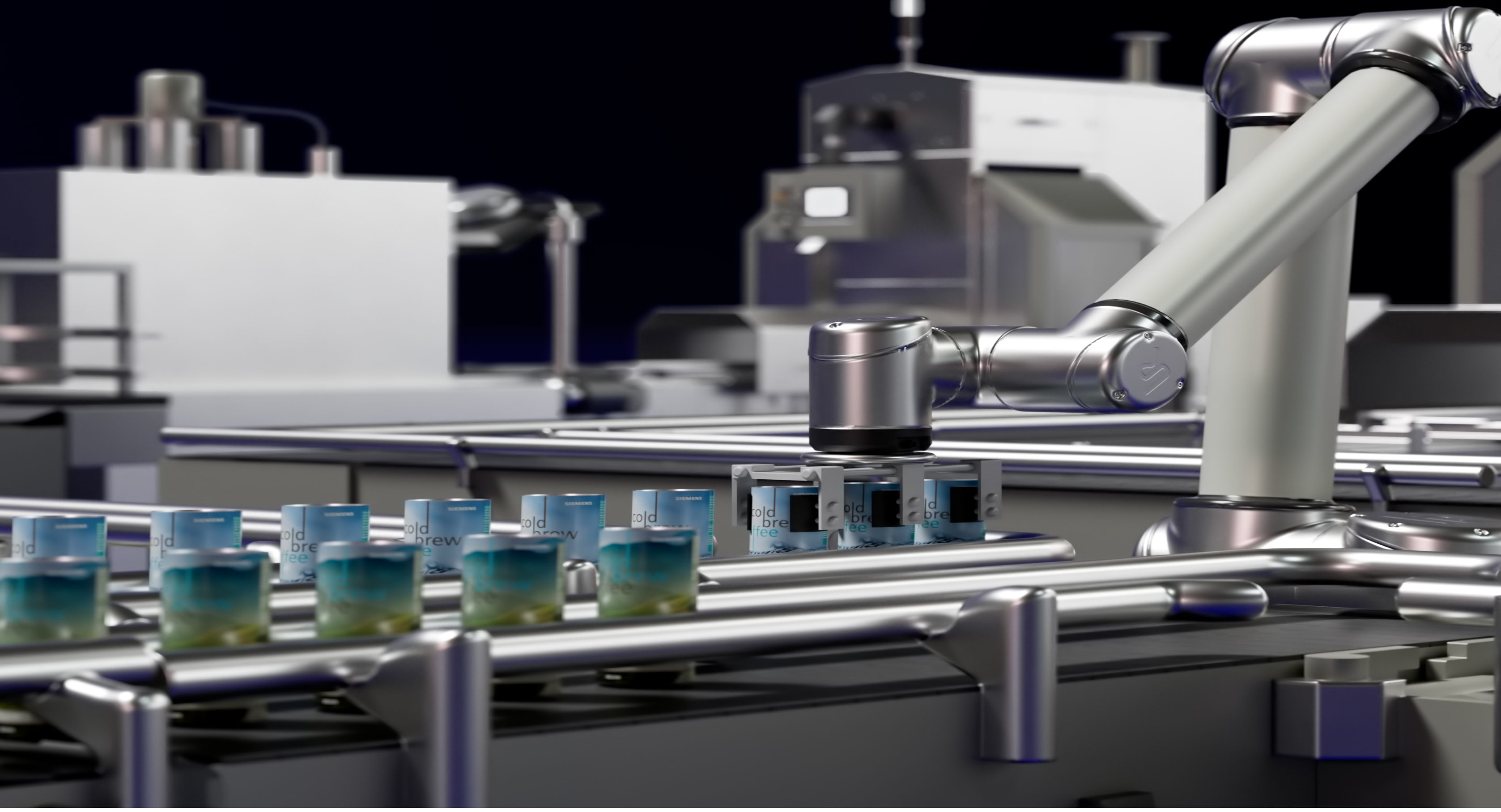

DIGITAL INDUSTRIES SOFTWARE

How do we create tomorrow’s factory today?

Use simulation to integrate robotic technologies into F&B factories

Executive summary

The Food and Beverage industry is battling a slew of obstacles, including adjustments in consumer expectations, shopping patterns, and a global pandemic that has wreaked havoc. Equally, these numerous challenges are rapidly changing, and behavioral adjustments most assuredly ascribe to recent international events. Respectfully, the more contentious consumers are now demanding a more expansive selection of higher-quality products at a reasonable price.

A few Food and Beverage Manufacturers understand these challenges. Moreover, the most resilient players have already begun rethinking their approach to manufacturing processes and are making strides towards developing better strategies. Granted, some of these successes are cause for optimism, but existing capabilities won’t be sufficient for organizations to keep pace over the next decade. The accumulation of challenges will only make things more difficult for brands and those who rely on them.

Abstract

In its current form, factories manufacture large quantities of a single product and slightly modify existing products to generate variations. While these product adaptations may temporarily placate consumers, buyers will need greater variety and alternatives. Brands must thoroughly reinvent their planning operations, capabilities, corporate performance, and processes to remain relevant and contribute significantly more.

Notably, comprehensive transformation planning will be paramount, including incorporating analytics and machine learning technology. However, brands will require new methods, talent, and governance to succeed. Contrary to how manufacturing has traditionally operated, factories should prioritize specific objectives that add considerable value rather than optimizing purely for unit efficiency – which is not sustainable for any organization

In comparison, many manufacturers are focusing their efforts on supply chain resilience. This adaptability can take various forms, from dispersed manufacturing hubs within each resale market to dynamically changing items. In terms of the latter, manufacturers may find that autonomous mobile robots (AMRs) and automated guided vehicles (AGVs) provide the necessary flexibility to address growing product complexity. Thus, what are ARMs and AGVs? **Autonomous Mobile Robots** (ARMs) are a type of robot capable of comprehending and navigating their surroundings. AMRs read and navigate their environment using a complex set of sensors, artificial intelligence, machine learning, and compute for path planning. **Automated Guided Vehicles** (AGVs) are computer-controlled and wheel-based load carriers that travel along the floor of a facility without an onboard operator or driver, guided by a combination of software and sensor-based guidance systems. AGVs provide the safe movement of cargo by following a predictable course. Both can encounter an unexpected obstacle while navigating their environments, such as a fallen box or a crowd of people.

It is important to note that it is critical to ensure that AMRs and AGVs safely perform their assigned tasks and add value to the facility before implementing these technologies. Not including these criteria in a comprehensive digital twin can result in the possibility of hindrances such as time loss, employee injuries, and reduction in investment. The automated factory of the future is almost inevitable but getting there will require streamlining operations now.

Only a few Food and Beverage manufacturers have fully automated or semi-automated their operations. On the other hand, automotive manufacturers are a sector that is rapidly adopting automated technologies. Food and Beverage Manufacturers can learn from automakers and leverage digital transformation to build automated factories that enable brands to be more adaptive, agile, and innovative.

For decades, industrial auto manufacturing has been an early adopter of robotics and other technological advancements. Historically, robotics has been one of the most effective methods for increasing the efficiency of extensive, often highly repetitive manufacturing processes. The era of mass production of a few products in a low-mix manufacturing process, on the other hand, is giving way to increased product personalization, necessitating a more flexible manufacturing process with less waste than ever before. Fortunately, the future of manufacturing is full of opportunities, with new technologies that leverage software and hardware capabilities to reduce waste and maximize process efficiency and flexibility. The insights gained through the digital twin and closed-loop optimization of entire facilities influence everything from raw material tracking to process optimization to hardware selection.

The zenith of these advancements is the transition to utterly flexible material handling via automated guided vehicles (AGVs) and autonomous mobile

robots (AMRs). These two technologies are poised to supplant an increasing number of static conveyance systems as the manufacturing industry transitions to more flexible manufacturing methods.

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Digital transformation spurs increased use of industrial robots

In 2020, approximately 384,000 industrial robots shipped worldwide. Asia/Australia installed the most units, with an estimated 266,000 units in 2020 alone. By 2024, industrial robot installations in Asia/Australia will reach an estimated 370,000 units. The global market for industrial robots, which was approximately 45 billion U.S. dollars in 2020, is expected to grow to about 102 billion U.S. dollars by 2027, as more businesses undergo a digital transformation by integrating technological equipment into their manufacturing processes. Since then, a market for industrial automation software has developed and will reach just under 40 billion dollars in the United States by 2024[1]

Robotics is a part of another industry: the automation market. This industry comprises various products and services, including relays, switches, sensors and drives, machine vision and control systems, and industry software development and services. Conglomerates like Siemens, Mitsubishi Electric, or General Electric are significant industrial automation vendors and industry software.[2]

Emerging Trends

Customization and adaptability are two of industrial manufacturing's hottest buzzwords. Customers desire bespoke items, whether a bottle of personalized aftershave with their name on it, a specially ordered vehicle equipped with all the features they require, or a pair of customized sneakers. Due to the overwhelming demand for customization, manufacturing is shifting toward high-mix production, producing millions of unique products in small batches.

At the same time, many products manufactured today are far too complicated for established automation technologies alone, necessitating the addition of manual assembly by workers to traditional robotics. For these reasons, humans are deemed valuable for their ability to comprehend and account for changes in a process quickly. However, what if you could build this degree of adaptability into automated processes?

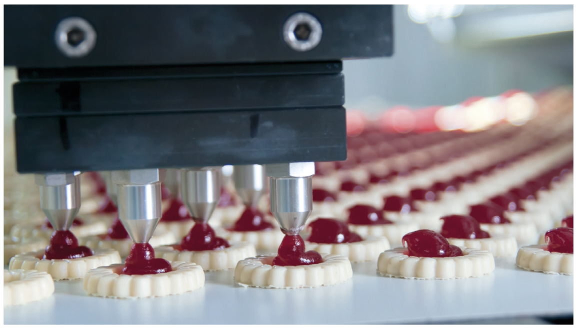
A flexible and automated (even autonomous) manufacturing system is the holy grail for many manufacturers seeking to leverage increasing product complexity into a competitive advantage while accommodating increased customization demands.

The ability to rapidly switch production between products will be a defining feature of businesses pursuing one-off lots and highly customizable products in the future. Although small lot sizes are not inherently problematic, current manufacturing processes cannot accommodate them without investing significantly in an increasingly complex infrastructure. Numerous businesses are seeking a more adaptable manufacturing approach to avoid this problem of exponential investments that may or may not resolve the issue.

Implementing flexibility

AGVs and AMRs are ideal for companies looking to increase plant flexibility and supply chain resilience. Continuous optimization of the entire process is achievable by removing static conveyor systems from the floor. How can machines be optimally positioned and clustered to minimize AGV route lengths? The resolution simulates the facility before deployment. With simulation, a new product launch that requires a rapid ramp-up of production will meet demand.

When AGVs and AMRs begin their route, one could prioritize the machines that produce these products, or perhaps the transition to dynamic conveyance is phased into complete a production run. Understanding the interaction of traditional and flexible conveyance systems is critical for efficient and economical operation.



Additionally, mobile robotics deployment is significantly less expensive than traditional conveyor systems. Because no foundation structure other than shallow charging tracks for AGVs is required, the impact on building requirements is minimal. For these reasons, Porsche chose to incorporate AGVs into the manufacturing process of the new Taycan electric vehicle. While Porsche chose technology to reduce their building requirements, smaller businesses may adopt the approach to scale production more quickly as they grow.

Often, the most significant barrier to deploying AGVs and AMRs is integrating these solutions into an existing operating facility. These devices must be aware of their environment to avoid colliding with stationary and moving obstacles, human or otherwise. They must reach and collect materials in a consistent and error-free manner. They must communicate with one another, even if the same company does not manufacture them. And most of all, they must share with the rest of the plant to control material through production or transit.

Integrate everything

Simulating new operations will minimize risk when updating an existing process or creating a new one. It obviates the need for upfront machinery investment before determining whether the new process will operate as expected on the shop floor. Without a thorough examination of the actions occurring within a plant, the latest equipment may be underutilized or even cause additional problems, resulting in a loss of investment. Similarly, the implementation of Internet of things (IoT) devices is required to close the loop between the digital twin and the physical processes after initiating new procedures. While these devices are integrated frequently into new manufacturing equipment, it is critical to consider how to utilize best the massive amounts of data they generate and gain crucial insight into the manufacturing process.

Process Simulate

Process Simulate, a component of Siemens Digital Industries Software's Xcelerator portfolio, validates and optimizes AGVs and AMRs at the cell and station level. The portfolio includes numerous tools for developing, validating, and operating AGVs, AMRs, and automation in their immediate environment. There are a variety of goals for deploying these technologies – perhaps to replace traditional conveyance systems or reduce the frequency of employees leaving their stations for required materials. But in almost all cases, implementing seven processes is crucial before physically integrating mobile robotics in a plant:

Cell and station level virtual commissioning
enables engineers to verify communication between devices and controllers across the plant floor and ensure proper signal exchange before installing physical equipment or initiating processes. This procedure is critical for later stages of the integration process when it comes to automating production processes. However, it ensures that an AMR can communicate easily with any machines it may encounter in the preliminary stages.

Robot reachability
is the validation that a robot's arm can reach a target location for stationary arms and those mounted on an AMR platform. Feasibility and operation simulations are run for the robotics programs within the digital twin to ensure all necessary locations are reachable without collision and whether it is an effective configuration for the task.

LiDAR sensors
are ubiquitous across AGV and AMR platforms and used both for navigation and safety, but not all systems run the same way. For AGVs, lidar sensor utilization detects reflectors' position within the work area, whereas AMRs require a virtual scan of the shop floor and continuously scan it as they go. Virtual detection range planning is also necessary so that the mobile platforms can navigate the floor without tripping a fail-safe function.

AGV/AMR

Robot synchronization validation becomes vital when deploying multiple devices to a floor. Without virtually planning and validating blocking zones for a robot, a deadlock will likely occur, and preventing this means keeping the plant floor running without unnecessary interruption.

Human safety

is critically important when deploying these technologies. Even in a fully automated facility, there will likely be people on the floor at some point in time, and the AMRs and AGVs need to handle the possible interruptions. Validating the safety of human operators means checking braking distances, detection range, deceleration rates, and much more for the entire fleet. This validation must be done extensively in the digital twin of the factory before physical deployment.

Route and operation validation

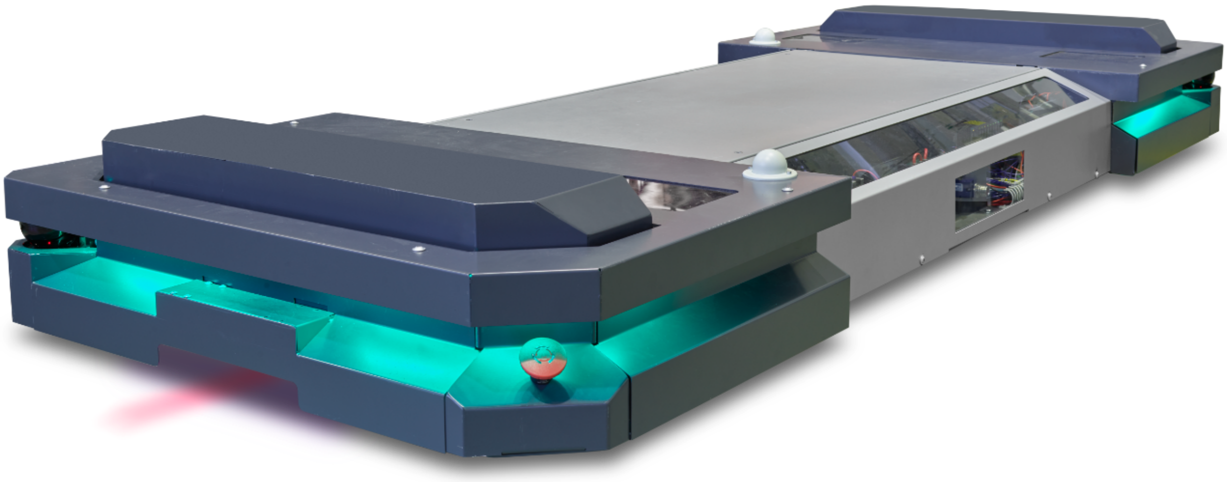
facilitate collision-free motion and operation for fork trucks, gates, turntables, and other shop floor devices within the digital twin. The use of point cloud (laser scan of the facility) collision capabilities for all work areas further extends the process.

Fleet manager connectivity

makes the entire system supplier agnostic by enabling connectivity to external fleet management

fleet managers. With this support, the vendor's fleet manager drives the AGVs and AMRs within Process Simulate to collect data on process effectiveness, communication reliability, and device interactions.

It is critical to validate each of these processes within the digital twin to reap the benefits of mobile robotics. While integrating new technologies is sure to reveal issues, locating them during virtual testing significantly reduces the resources required to do so physically. Additionally, when a new process is needed, validation can occur while the previous techniques continue to operate, increasing flexibility.



Plant Simulation

Tecnomatix Plant Simulation is also a component of Siemens Digital Industries Software's Xcelerator portfolio, validates and optimizes AGVs and AMRs at the fleet, plant, or facility level. To balance time, compute power, and granularity for such comprehensive simulations, the detailed study results available from Process Simulate, such as cell timing or cell sequences, can be applied in Plant Simulation as it scales up to the complete production facility. Robots' task times are the most common simplification, though the method may change depending on the application.

A few of the most common attributes validated before installing mobile robotics platforms are system throughput (units per hour), path optimization, fleet sizing, control strategies, and operational efficiency. Battery life and charging characteristics are also crucial elements when sizing a fleet. Without simulation, the fleet may underperform once operated, requiring additional investment, delaying reaching production capacity, or overperforming, leading to underutilized devices and lost investment. That is why in most cases, it is imperative to use the simulation for these six areas of upfront planning:

AGV requirements

A logical starting point for planning the addition of AMRs to a plant floor is to determine the number of devices required to support the new processes. For example, suppose a battery manufacturer wishes to deploy a fleet of AGVs to transport workpieces between manufacturing stations. The best method for determining how many are required is to conduct a throughput and cost analysis. By simulating the comprehensive digital twin, multiple attributes are varied and tracked to select the optimal number of AGVs. For this example, the manufacturer may wish to record the volume of batteries manufactured, the number sold, and the unit cost of production while increasing the number of AGVs in the simulation.

These are plotted against the number of manufacturing stations and automated guided vehicles in operation. Plant simulations are helpful to determine the optimal number of AGVs. Whichever chosen metric —cost per unit, production speed, or another—is up to the individual business, but quantifying the benefits of the upgrade is critical during the initial stages of adoption. The simulation is typically set up through an experiment manager to run multiple scenarios returning the optimal one (for example, number of AGVs or AMRs) in a report driving investment decisions. This process is critical for both the end-user and the AGV system integrator.

Path optimization and fleet manager control strategies

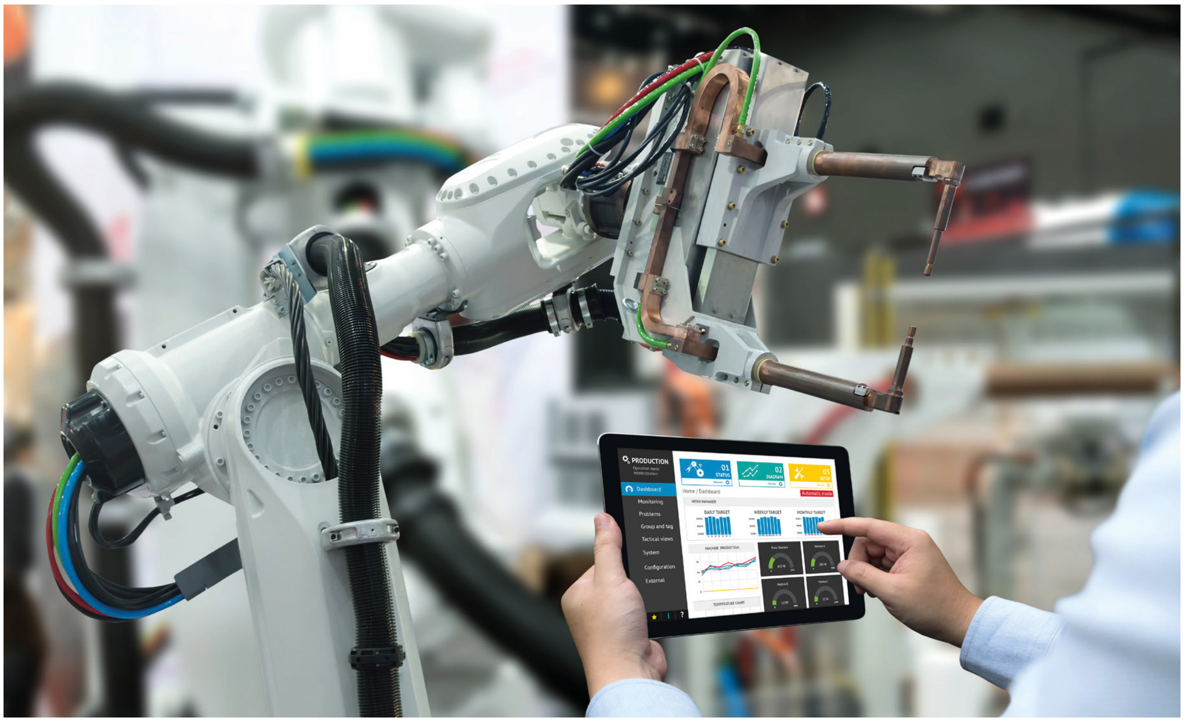
For understanding conveyance needs as well as cell and station level behavior, the next step is to let the AGVs operate within the virtual factory. Recoding each device's locations and paths happens during the test. After running this virtual test for an eight-hour shift, or another representative amount of time, unaccounted inefficiencies not included in the initial plan may arise. The AMRs may create a bottleneck as they move through a section of the plant floor. Some AMRs may not reach the far corners of the facility, while others may meet their carrying capacity before serving specific areas in need. More may fail to access the required machines for lack of adequate charging. Even worse, some could die on the floor from a lack of charge due to insufficient battery size or faulty charging times. All these situations may lead to identifying a need to add AGVs beyond the nominal fleet size.

These are critical problems to understand and solve while deciding a fleet management control strategy and before spending time implementing, configuring, and programming the fleet manager. Solving these problems as they arise during production could lead to expensive rebuilds of the charging areas to reach all machining stations or more direct programming to force an AMR to check a defined area first before continuing its regular route.

Strategies for route optimization and fleet manager control

The next step is to allow the AGVs to operate within the virtual factory to understand conveyance requirements and cell and station level behavior. Recoding each device's locations and paths happens during the test. After running this virtual test for an eight-hour shift, or another representative amount of time, unaccounted inefficiencies not included in the initial plan may emerge. As the AMRs pass through a section of the plant floor, they may create a bottleneck. Again, some AMRs may not reach all targets, while others may get their carrying capacity before reaching areas in need of collecting more items. Additional vehicles may not access the required machines due to inadequate charging, either stopping in their tracks or returning mid-travel for charging without completing their assignment.

These are critical issues to understand and resolve ahead of implementing, configuring, and programming the fleet manager. Solving these issues during production may require costly rebuilds of charging areas. Continuously, to ensure that they reach all machining stations or more direct programming, they need an AMR to check a defined area before continuing its usual route.



Closed-loop digital twin

The previous processes are not limited to preinstallation practices either. Given a comprehensive digital twin of the facility and the ability to collect and manage IIoT (Industrial Internet of Things) in a platform like MindSphere®, the industrial IoT as a service solution from Siemens' Xcelerator, closing the loop between simulation and production provides accurate insights for continuous optimization and more effective troubleshooting. Testing enhanced or amended fleet manager programs using accurate historical data available through MindSphere will reduce, to zero, the need to run iterations on the production floor and allow responding to behavior changes promptly, keeping fleet operation optimized.

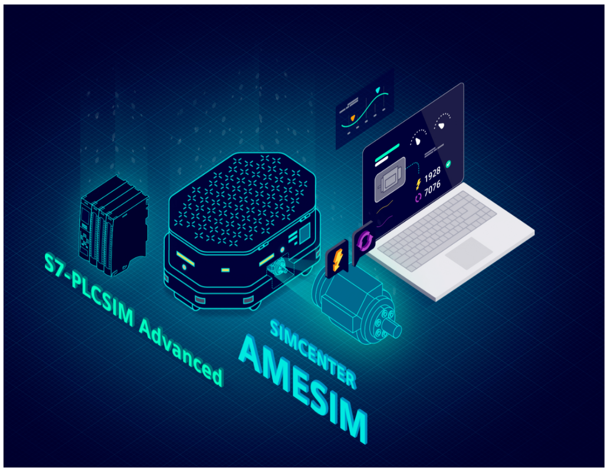
Battery validation

For AGVs, this may be the most critical validation step. In simple workflows for AGVs, all devices follow a single path. They leave the charging station and are directed down the line, passing all the required stations for the task it is fulfilling before dropping off the workpiece and returning to the charging area. But should an AGV need to make multiple stops, the battery charge could drop too low to operate correctly. For AMRs, this is not as big of a problem since they can be re-outed and returned to a charging bay.

AGVs must stay in the line. So, if a single device loses power, the entire fleet will eventually stop and drain their remaining power waiting for the leading AGV to advance stations. Battery validation is needed to examine and define both the available battery power and the length of the charging lane to ensure none of the AGVs will stop along the line and bring the facility to a halt. This solution is dependent on interactions the AGV has with machines and workers on the floor, making it a priority to ensure an AGV can make it to the charging station even while encountering delays.

Line integration

Line Integration (line-level virtual commissioning) is the process of integrating a head-level programmable logic controller (PLC) or a set of PLCs (Programmable Logic Controllers) with device controls, station PLCs and fleet management. This process is an overly complex procedure that is usually prone to additional errors discovered during production ramp-up. Virtually commissioning or testing line integration with the digital twin significantly reduces surprises and even enables the discovery of improvement opportunities by observing the system's behavior on the facility's comprehensive digital twin in Plant Simulation. Commissioning can be carried out entirely virtually when using Plant Simulation for the production digital twin, Siemens PLCSIM Advanced for virtual PLC controls, and Siemens SIMOVE for AGV control and fleet management.



Conclusion

Alternatively, for Food and Beverage Manufacturers, AGVs and AMRs are two of the best solutions available to brands seeking a more flexible manufacturing process, whether to meet the increasing demand for increasingly complex products or bolster supply chain resilience. Proportionately resolving current methods is essential for enabling these recent technologies and integrating them into a more comprehensive strategy. And the pressure is only increasing to adopt these approaches as manufacturing moves toward greater customization and eventually lot sizes of one. Integrating advanced material handling with disparate machine builders, software providers, and established processes requires a comprehensive solution based on a digital twin to understand better how the processes are operating and optimize them with more excellent knowledge.

Working in the virtual world before committing to physical implementation enables manufacturers to implement process simulation combined with plant simulation to achieve flexible production for increasingly complex and customized products. With our software expertise and manufacturing background, Siemens is a great partner to bring the tools of tomorrow's factory to businesses today.

References

1. Statista Research, Oct. 2021.
2. Statista Research, Nov. 2020.

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For additional numbers, click here.

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Siemens Digital Industries Software is driving transformation to enable a digital enterprise where engineering, manufacturing and electronics design meet tomorrow. Xcelerator, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, helps companies of all sizes create and leverage a comprehensive digital twin that provides organizations with new insights, opportunities and levels of automation to drive innovation. For more information on Siemens Digital Industries Software products and services, visit siemens.com/software or follow us on LinkedIn, Twitter, Facebook and Instagram. Siemens Digital Industries Software – Where today meets tomorrow.

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