DIGITAL INDUSTRIES SOFTWARE

Digital solutions for specialty chemicals

How integrated manufacturing operations management enables smarter manufacturing

Executive summary

"Leaving well enough alone" has never been an option for manufacturers in the chemical industry. Indeed, this marketplace is characterized by a constant drive toward inventive – and sometimes adventurous – efforts to find, extract and refine raw materials, then formulate and produce finished products, all in a manner optimized for efficiency. The chemical industry is expected to completely reinvent itself in the coming decades. Efficiency and resiliency are crucial to remain competitive in the most volatile commodity pricing markets in history and, simultaneously, be on a path towards decarbonization. To meet these requirements, manufacturers need to rely on digital innovation to dramatically improve operational and maintenance performance to achieve higher productivity levels, as well maximize production while reducing carbon emissions.

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Abstract

Digitalization, accelerated by new global challenges, is changing business models and manufacturing approaches across the spectrum of industries, including chemical manufacturing. The pace of innovation in digital technologies along with the ability of these technologies to disrupt established practices is becoming a key factor in global competition among chemical manufacturers. These changes may increase pressures on chemical manufacturing professionals, but at the same time they open up new business opportunities.

How can your chemical company seize upon these opportunities? How can you invest strategically and wisely in digital systems so your company can reap the competitive advantages they offer? Conversely, how can you avoid risky investments that could place your company in a financially precarious position?

This paper sets out to address these questions in a meaningful and practical way. Our goal is to properly characterize and frame the challenges you face – challenges that take on a distinctive quality given the particulars of chemical manufacturing –and then to discuss the digital tools that will help you tackle these challenges today and into the future.

The importance of investing in MES and MOM

Joining virtual and real production

Central to these digital tools is an integrated manufacturing operations management (MOM), which addresses the critical domain where virtual and real production converge. MOM links enterprise resource planning (ERP) and product lifecycle management (PLM) solutions, which integrate data, processes and business systems into the manufacturing floor's production machinery and automation. A MOM solution consists of several key systems, including advanced planning and scheduling (APS), the manufacturing execution system (MES), the quality management system (QMS) and manufacturing intelligence (MI). Importantly, it is neither necessary nor desirable for a manufacturer to invest in a full-orbed MOM and implement these components all at once. Instead, we recommend a stepwise approach in which the manufacturer makes incremental investments that generate immediate returns, which can then be invested in the next MOM component.

An integrated MES is arguably the centerpiece of MOM technology. For many chemical manufacturers, it is the most critical next step to take on your digital journey. This paper uses integrated MES to illustrate the value of digitalization, though some chemical manufacturers may have reason to choose a different starting point in their MOM implementation. We will address these other starting points along the way.

It is our contention that you will achieve and sustain a competitive advantage as you continue your digital journey through a strategic, stepwise implementation of a MOM solution. We offer unique "end-to-end" visibility into the production process to optimize quality and achieve operational excellence, allowing decision-makers to rapidly identify production and quality issues, and other areas for process improvement.

Bridging the digital gap

Digitalization is not new to chemical manufacturers, most of whom have adopted both ERP and manufacturing automation systems. These two digital tools sit at opposite ends of the manufacturing enterprise. An ERP

digitalizes and streamlines front-end business decisions related to anything from supply chain to accounting and procurement. Manufacturing automation accelerates production processes and ensures process consistency. In between the two, chemical manufacturers must communicate a wealth of information, including orders, product formulations and recipes, manufacturing schedules and production line assignments, human and material asset allocation, quality procedures and processes, manufacturing results and much more.

Until recently, most chemical manufacturers have provided this communication link through homegrown solutions or third-party custom systems. But two factors have conspired to create a situation in which the demands on these systems are starting to outstrip their capabilities: (1) the very nature of the chemical manufacturing industry, and (2) evolving market conditions. Let's take a closer look at these two factors and see how they suggest some fundamental challenges the industry faces. Then we will discuss an approach to continue digitalization that successfully addresses these challenges.

Digital solutions must be suited to the needs of the chemical industry

Usually capital- and technology-intensive, chemical manufacturing is a process industry highly dependent on the quality of raw materials and the reliable functionality of equipment and instruments. It features a long industry chain, various control points and complicated technological processes tied to chemistry. The very nature of chemical manufacturing makes safety an overarching consideration.

Today's chemical industry is characterized by:

- Long plant lifecycles with a highly fragmented data landscape
- Continuous, safe, secure and reliable operations that take into account different user groups and capabilities
- Globalized, evolving markets in which companies must address the complete supply chain and production lifecycles
- Integrated solutions adapted to local conditions

These characteristics are common to the chemical industry and influence the digitalization needs of any manufacturer. But important distinctions also exist

among different sectors of the chemical industry, which also create differences in those sectors' digitalization priorities and investment strategies. Continuous manufacturing processes for petrochemicals, as well as large batch processes for basic chemicals and intermediates, could certainly benefit by digitally managing manufacturing execution with integrated MES and other MOM systems, but the need for integrated digital solutions to perform these functions is not as acute or urgent as it is for makers of fine and specialty chemicals. For this final sector, the advantages of digitalization in manufacturing operations are especially valuable.

Digital solutions for fine and specialty chemical manufacturers

One of the most consequential features of fine and specialty chemical manufacturing is its dual value chain. The primary value chain is the manufacture of the semi-finished product through batch production processes, while the secondary value chain involves packaging and palletizing to create the finished product. This dual value chain is of particular importance with regard to the management of manufacturing operations, because the two chains are quite distinct during both design and manufacturing stages. Often the two chains manage manufacturing operations with two different digital systems. One highly valuable digitalization step for these manufacturers is to combine the two value chains by supporting them with a common, holistic digital solution. More on this later.

While other chemical manufacturing segments may also feature a dual value chain, what makes it especially relevant to the digital needs of fine and specialty chemical manufacturers is the sheer volume of products each manufacturer makes. These companies may offer thousands of products, in some cases more than 25,000 products. Separately managing the process and packaging steps for this many products becomes exceedingly time- and labor-intensive and prone to errors. By comparison, petrochemical companies may offer 10 products, and basic/intermediate chemical manufacturers, perhaps 250 products. When the number of products you offer is two orders of magnitude greater than other chemical manufacturers, the demands on your manufacturing operations are very different.

Manufacturing operations have many different facets, each with its own challenges to optimize and improve the overall process. Every single item – each formula, recipe, raw material, manual or automated task, equipment or quality inspection – is like a cog that must work in concert with all other cogs in a large machine.

Multiply this number of moving parts by 25,000 and the demands on MOM functions come into sharp focus. Fine and specialty chemical manufacturers must switch production lines from one product to another with great frequency. They face a remarkable number of new product introductions (NPIs). Data generation, aggregation, contextualization and management are critical.

And of course, as a company you would like this machine to run as fast and efficiently as possible. All the products, NPIs, integration with research and development (R&D) and recipes must be managed efficiently. Visibility is needed in batch execution, order tracking, batch recording, material tracking and production key performance indicators (KPIs). Keeping everything aligned and synchronized is of paramount importance.

For fine and specialty chemical manufacturers operating multiple plants in diverse locations, the picture for operations management is that much more complex. Each individual formula may be relatively simple, but the level of complexity quickly grows when one considers the multiple recipes each formula may require, accounting for different raw material profiles, equipment operational profiles and even ambient climate conditions at plant locations.

Further complicating the challenge is the accelerating pace of product change. Changing one parameter in a formulation can have a cascade effect on many other facets of the production chain: raw material availability, quality specifications, shop floor resources, regulatory compliance requirements, specific manufacturing recipes for each production line and more.

These characteristics are built into the fabric of fine and specialty chemical manufacturing. They alone provide more than sufficient justification to consider new investments in digital solutions. Today's market forces intensify the need and also the shape of specific challenges that digital solutions must address.

Digital solutions must address market trends

In the specialty and fine chemicals sector, changes in the market and consumer demands are forcing manufacturers to rethink the way they develop, produce and distribute their products. Evolving market conditions increase the urgency with which these manufacturers are considering investments in digital solutions. Four market trends in particular are having the greatest impact:

1. **Production capacity and moderate growth in production demand**
   In the recent past, the chemical industry experienced relatively strong growth, which prompted an increase in production capacity. Today, production capacity exceeds demand. Additionally, chemical manufacturers are operating under the cloud of recent uncertainties created in the global marketplace due to geopolitics.

   This means chemical manufacturers are moving their focus from production capacity to production cost reduction strategies and process efficiencies. Significant opportunities for reduced costs and increased efficiencies are generated by implementing digital solutions.

2. **The rise of mergers and acquisitions**
   Linde and Praxair. Bayer and Monsanto. Dow and DuPont. ChemChina and Syngenta. These noteworthy mergers and acquisitions reflect a growing trend in the chemical marketplace, which makes standardization more and more important. Manufacturers need to align the production processes of acquired plants with the ones already under their control. They need to ensure consistent, high-quality output across all plants. Standardized manufacturing operations management is a necessary component of efforts to bring about these outcomes. Standardization also helps to minimize implementation costs across all plants.

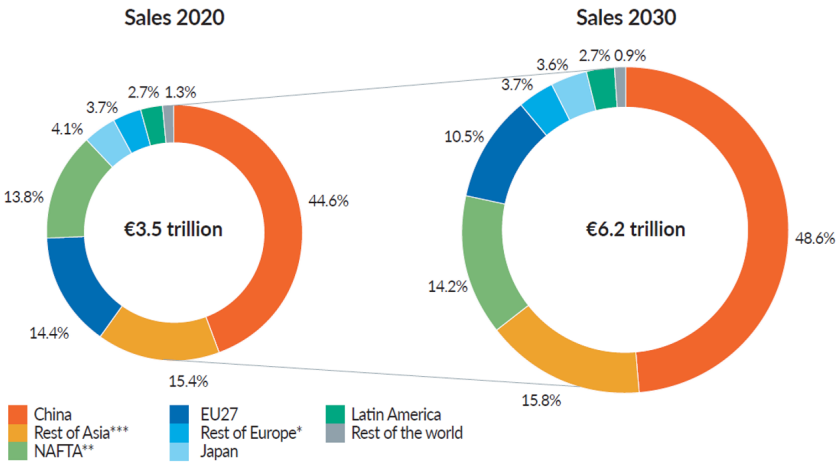
In this climate, chemical manufacturers also need assurances that today's digital investments can grow into tomorrow's digital ecosystem. They need software that is:

Scalable – able to add greater capacity, such as more users, facilities or transactions.

Extensible – able to add functionality, such as modules related to supplier management.

Integration-ready – able not only to stand on its own and offer a full breadth of capabilities in its

World chemical sales 2020-2030



Source: Cefic Chemdata International
* Rest of Europe covers UK, Switzerland, Norway, Turkey, Russia and Ukraine
** North American Free Trade Agreement
*** Asia excluding China, Japan and South Korea

functional area, but also to interface with other systems and communicate seamlessly via an interoperable platform.

3. **Increasing regulatory and legal costs**
   Regulation is understandably a considerable aspect of chemical manufacturing, given the dangers associated with chemical processes. Every process must be clearly defined – what is being done, who is qualified to do it, etc. – and then monitored and verified.

   Fine and specialty chemical manufacturers must transparently manage the increasing production complexity they are experiencing. Transparency is also needed regarding energy consumption, environmental pollution and other factors connected to environmental regulation. These manufacturers must not only achieve an acceptable level of quality control, they must also demonstrate it to regulatory authorities. Digitalization makes adherence to these growing requirements technologically and economically feasible.

4. **Growing importance of green chemistry**
   Although growing environmental regulations increase the pressures on fine and specialty chemical manufacturers to advance their company's sustainability efforts, other market pressures are also driving the growth of green chemistry. The rising visibility of green business philosophies and green companies, with their appreciation of the environment, create competitive pressures on companies in the same manufacturing space. They must work toward eliminating the chemical impact of their raw materials, products and by-products on the environment. Today, it is not only the product that needs to be sustainable and environmentally friendly – energy efficiency in producing and implementing zero-waste initiatives become competitive advantages, too.

   Manufacturers also want to attract new environmentally conscious buyers by offering green formulations. This entails a need to deploy new eco-friendly formulas quickly – while also ensuring new formulations continue to meet customer requirements for the end product (a green formulation for a cleaning agent is valuable only if the new agent still cleans).

Combined with the inherent characteristics of fine and specialty chemical manufacturing, these four market trends create a set of industry challenges – challenges that can best be met by integrated MES and other MOM-based digital solutions.

Fundamental challenges for fine and specialty chemical manufacturers

Earlier in this white paper, we mentioned digitalization may create new pressures on chemical companies, but at the same time, digitalization is creating opportunities to successfully meet the fundamental challenges the industry faces. What are these fundamental challenges?

HSSE

Compliance is the watchword when it comes to health, safety, security and environment (HSSE). Chemical manufacturers need solutions that reliably track products, processes, batches and orders in ways that satisfy growing and evolving regulatory requirements, both for plant safety and the environment. They also need the means to enforce all operational procedures related to the safety of manufacturing personnel – and to demonstrate enforcement to any regulatory bodies or auditors that ask for verification. And they must meet the growing demand for new eco-friendly products by providing adequate support for both R&D and NPI efforts.

Costs

Because the specialty and fine chemical industry can expect no significant increase in product pricing in the foreseeable future, any margin increase depends on cost reductions. Moreover, market competition makes it paramount to maximize these cost reductions as much as possible, while also maintaining product quality and HSSE compliance. Capital investment in digital technologies contributes to cost reduction goals only to the extent these technologies produce a high return-on-investment (ROI). Such returns result when digital technologies support root-cause identification for any asset inefficiency and failures, and then enable prompt correction.

Standardizing and optimizing processes and organizations are key levers in successful cost reduction using digitalization. A solution that supports standardized systems and processes will help manufacturers to optimize the cost of rollouts and manufacture products in a consistent way across many plants, especially when those plants are subject to diverse environmental and geopolitical conditions around the globe.

Flexibility

Consumers want individualized products – but at the prices they would pay for mass-produced goods. As a consequence, production has to be more flexible than ever before. Individualized mass production is accomplished more efficiently using a modular approach to production that creates the needed flexibility.

Flexibility is also needed for a manufacturer to accommodate plants in different areas of the world. For example, each plant is tasked with producing the same finished goods as every other plant in the company but must do so despite the variations in raw materials or fuels that result from having different suppliers. The need for flexibility is driving digitalization of the entire supply chain, and the digital technology chosen must provide that flexibility.

Time-to-market

Escalating and accelerating changes in customer demands also drive the need to bring new products to market promptly. Innovation cycles are getting shorter and product variety is increasing. To introduce new products to the market as quickly as possible, manufacturing processes – in concert with business processes – require the capacity for rapid adaptation. As manufacturers speed up their product development processes and their introduction to production facilities, an integrated digital approach to product and process development and implementation is becoming essential.

Output

Efficiency is the watchword as chemical producers seek to optimize manufacturing output. Efficiency is addressed by monitoring and increasing the availability, performance and quality of assets. Manufacturers must not only monitor overall equipment effectiveness (OEE) but also monitor and manage OEE changes that occur depending on the products each manufacturing line is producing. A myriad of possible scheduling combinations of production tasks must be considered to optimize resource assignment and utilization. Detailed production scheduling is fundamental to delivering output as fast as possible.

Synchronization of tasks between departments is critical to ensure production is performed efficiently with the proper material flow at the right time. In the dual value chain of fine and specialty chemicals, synchronization includes coordinating production so a batch completes processing just-in-time (JIT) for delivery to the filler at the beginning of the packaging line.

Meeting these challenges in a way that not only addresses immediate needs but also equips your company for the future requires some deliberate, strategic decision making – the kind that considers how your manufacturing enterprise will navigate its continuing digital transformation.

Digital transformation and the Siemens approach

When engaging with our fine and specialty chemical manufacturing customers, we often see a system landscape composed of multiple individual legacy and custom solutions. The gap between ERP and shop floor automation is often bridged by such solutions, but this approach usually does not optimize production scheduling and changeover. Moreover, with new demands placed on these custom systems by evolving market trends, it is nearly impossible to continue adapting them quickly enough to keep up with NPIs or the accelerating changeovers required by the smaller and more numerous batches that fulfill growing product individualization. To optimize manufacturing operations, manufacturers need to plan, control, and adjust their production operations to make it more efficient.

To make good decisions, they must be able to track production time, manage the bill of material and bill of process, analyze performance, and manage quality operations.

To address today's fundamental industry challenges of HSSE, cost, flexibility, time-to-market and output, a digital solution must offer speed, flexibility, quality and efficiency. Thankfully, current digital technology has achieved these characteristics. In particular, digital technologies that provide effective, efficient, standardized solutions for manufacturing execution and manufacturing operations management are poised to address the challenges fine and specialty chemical manufacturers face.

As we consider an effective approach to manufacturing digitalization for fine and specialty chemical manufacturers, let's look first at the broader picture of digital transformation and then focus in on integrated MES and MOM technology.

Holistic digitalization and digital twins

Siemens offers a holistic approach that transforms a traditional dual value chain into a unified, integrated product and production lifecycle – from product design to production planning, production engineering, production execution and service. Only a fully digitalized business model with a consistent digital thread has the power and flexibility to speed up processes and optimize production operations. This also requires a joint data storage and data management system – a unified data backbone that delivers a collaboration platform throughout steps of the value chain.

The Siemens approach is built on digital twins, virtual representations of physical products and associated processes. A common platform enables integration of the digital twins of product and performance, creating support for the entire value chain. Employing digital twins, manufacturers gain foresight by simulating product, people, processes and resources in the virtual realm before implementing production on the manufacturing floor. They gain additional insights by matching real-world to predicted performance, and they can use those insights to drive continuous improvements.

Beyond individual plant operations, a unified, integrated approach means processes can be standardized via the digital twin and easily rolled out to different plants. They can quickly be up and running in a standardized, transparent way at full speed.

Ultimately, a holistic value chain is supported by a cloud-based, open Internet of things (IoT) ecosystem, which enables companies of every type and size to unlock their data assets and put them to profitable use to increase availability, quality and efficiency across the value chain.

With this all-encompassing future vision, many manufacturing companies ask whether they must take the plunge and implement a complete digital transformation all at once. Not at all! The Siemens approach is indeed holistic, but it also enables a modular, stepwise implementation with ongoing ROI that supports the next module or step.

The typical starting point of the digital journey for fine and specialty chemical manufacturers is the current ERP, manufacturing automation and siloed elements of the MOM system landscape. From there, manufacturers are able to incrementally integrate legacy and custom functionality systems. Eventually, a manufacturer will transition from each legacy system to a next-generation software solution. This approach protects earlier investments while it starts building towards a flexible and efficient unified digital enterprise.

Integrated MOM is a key solution in digital transformation

In today's business climate, it is essential for fine and specialty chemical manufacturers to make rapid, informed decisions in fast-changing operating environments. MOM software enables this kind of decision making. MOM ensures quality and efficiency are built into the manufacturing process and are proactively and systematically enforced. An integrated MOM solution connects multiple departments and stakeholders in one facility; and multiple plants, sites and vendors' live production information in multi-site enterprises. MOM integrates easily with equipment, controllers and enterprise business applications. The result is complete visibility, control and manufacturing optimization of production and processes across the enterprise.

MOM tracks product and order details on the plant floor, collects transactions for reporting to financial and planning systems, and electronically dispatches orders and manufacturing instructions to shop floor personnel. It also helps eliminate human error in manufacturing by providing real-time quality data checks, yield monitoring, automatic enforcement of specifications and business rules and as-manufactured lot, batch and finished product traceability – all resulting in improved product and process quality and higher productivity. Paperless manufacturing enabled by MOM helps to reduce scrap and eliminates paperwork errors and redundant checks.

For larger fine and specialty chemical manufacturing companies, a MOM solution monitors and synchronizes manufacturing activities across globally distributed plants and links them in real-time to the enterprise for optimal performance.

An integrated MOM also enables manufacturers to aggregate, analyze and transform data into actionable information that can be reported back to both product development and production planning, creating a closed-loop decision environment for continuous optimization.

As manufacturers implement integrated MOM, a standardized solution enables them to lower total cost of ownership with delocalized installation. MOM functions can be implemented in steps so that legacies are replaced in a seamless way. The holistic platform that supports an integrated MOM also facilitates a personalized user experience and enables manufacturers to rethink work center ergonomics, data consumption and other factors that affect manufacturing efficiency.

For many fine and specialty chemical manufacturers, the most beneficial first step of MOM implementation is an integrated MES. But other options discussed below may prove to be better starting points for particular manufacturers, depending on their current systems and near-term needs. A manufacturing operations management solution is centered around the MES pillar: managing the execution of manufacturing processes is the core of MOM. Nevertheless, we talk about a MOM solution because within such a solution, the MES domain is tightly integrated with other domains:

- Planning and scheduling
- Quality
- Manufacturing intelligence

Integrated MES

MES provides **vertical integration** that bridges the gap between ERP and manufacturing automation as well as PLM.

MES enables **standardization of production processes**, making sure manufacturing workflows are rolled out easily and consistently. Best practices can be clearly identified and adopted to help increase production efficiency and quality.

MES provides real-time **orchestration** of manufacturing orders and tasks, stitching all the separate production steps and resources together into a unique and efficient manufacturing flow.

While sequencing and coordinating flexible and complex production operations, MES provides automated **track-and-trace of manufacturing history records** and ensures complete visibility into every operation on the shop floor.

MES grants **end-to-end enforcement** of all manufacturing resources:

Material – Ensuring the right material is available, unexpired and used per the latest revision of the bill-of-materials (BOM)

Operator – Ensuring correct operator actions with electronic work instructions (EWI) and certifying that each operator is properly trained and allowed to perform each task

Equipment – Ensuring the right equipment is available, well maintained and certified for use

Other MOM pillars

Integrating **advanced planning and scheduling** enables you to efficiently manage orders and sequencing with product lines, formulas and recipes and production assets. It gives manufacturers the opportunity to plan and schedule orders based on different optimization criteria; for example, minimizing the equipment setup or clean-up time.

Integrated quality management improves visibility and coordination of all quality measures, from formulation to at-line and off-line laboratory quality test execution and monitoring, helping to ensure and demonstrate full compliance with regulations.

Enterprise manufacturing intelligence (EMI) provides full visibility into process and production l performance by aggregating raw data collected from the real production environment and transforming it into KPIs, shown with simple and intuitive graphical dashboards and graphs. EMI data analysis, contextualization and visualization capabilities enable manufacturers to close the manufacturing loop and implement continuous product and process improvements to maintain a forward-looking competitive advantage.

A specific function within the manufacturing intelligence pillar is managing manufacturing performance focused on **overall equipment effectiveness**: asset monitoring, analysis equipment performance and downtime, and detailed failure explanations help manufacturers to measure and track how well the manufacturing operation resources are being used, and to identify opportunities for greater usage and manufacturing efficiency.

How integrated MOM supports fine and specialty chemical manufacturers

By bridging the gap between existing ERP and plant automation systems, an integrated MOM generates many of the benefits needed by fine and specialty chemical manufacturers to address today's fundamental manufacturing challenges. These benefits enhance product and process efficiency, quality and visibility, also feeding a closed loop of continuous improvement.

Manufacturing efficiency

During production execution, the scheduling of product batches and filling of orders is crucial to meeting customer demands related to time, quality and cost. Although ERP systems are designed to optimize business processes, an integrated MOM optimizes scheduling and order sequence for the production floor. It supports efficient changeover to accommodate a rising number of products. With real-time asset and production monitoring, integrated MOM helps to minimize equipment downtime, troubleshooting and other nonvalue added tasks. An integrated MOM enables prompt correction and optimization by efficiently identifying root causes of asset inefficiencies and failures.

Product and process consistency

In process manufacturing, an integrated MOM helps ensure tasks are performed at the right time and for the right duration with the right materials, assets, settings and processes. It also provides visible material tracking, which ensures efficient use of the correct raw materials. When called for, the system immediately demonstrates the correct materials and processes were used. And as a manufacturer extends manufacture of a particular product across multiple plants in diverse geographic locations, digital standardization enables optimized cost of rollouts and ensures product consistency.

Visibility across the dual value chain

There are significant advantages to combining the two value chains of fine and specialty chemical manufacturing into a common, holistic one supported by integrated MOM. For instance, all information available in the formulation of product can seamlessly be used in the artwork design of the label. An integrated MOM supports the selection of information to be printed on the label for each country or regulatory jurisdiction.

The integrated MOM also aggregates manufacturing data, which can then be contextualized with an integrated enterprise manufacturing intelligence solution. Smart and easily understood dashboards and KPIs make this intelligence accessible to all stakeholders in a way the encourages operational excellence.

Conclusion

Unprecedented aptly describes both the pressures that fine and specialty chemical manufacturers face and the opportunities they can seize to gain significant advantages over the competition. An integrated MOM implemented via incremental investment in MES, APS, QMS and EMI represents a strong set of steps toward full digitalization. Integrated MOM both addresses the pressures and brings the opportunities to fruition.

With each MOM software solution, you can incrementally digitalize and seamlessly integrate product and production lifecycles for flexible, scalable production processes that maximize your responsiveness to real-time market and manufacturing events.

Leveraging the capabilities of the Siemens Xcelerator portfolio, we build a solution providing full visibility on production performance, and therefore enabling sustainable manufacturing processes.

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Learn more

Discover in more detail how our solution can help your manufacturing processes. In our on-demand webinar 'Enabling continuous chemical industry improvement through digitalization', we discuss how our solution solves industry manufacturing challenges.

The webinar will present a digitalization and automation demonstration and case study that reveals the cost-reducing benefits for manufacturers.

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