Manufacturing Excellence in Specialty Chemicals: Six Essential Levers

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Introduction

The specialty chemicals landscape is undergoing significant transformation. Many large, integrated chemical companies are increasing their business footprint in specialty chemicals. Abundant merger and acquisition activity (M&A) is creating new specialty-exclusive companies, as well as sharpening the specialty focus of existing chemical players. Activist investors and private equity are further fueling both of these trends, challenging the status quo and disrupting traditional business portfolios. While this transformation process is driving many changes, a key outcome is that competition is intensifying in specialty chemical markets.

Producers are fighting to maintain their differentiation in this environment by moving closer to customers with tailored product and service offerings, as well as accelerating new product innovation to both defend existing markets and enter new ones. At the same time, end-use markets for specialty chemicals are becoming more demanding, with requirements becoming progressively more sophisticated and stringent. The net result for specialty chemical producers is that business and operational complexity is growing rapidly as they manufacture more products, serve more customers and operate more complex assets. Producers are increasingly challenged to manage this rising complexity in a way that both satisfies customers and maintains profits. Competitive differentiation and business performance are clearly at risk.

Manufacturing Performance is Pivotal

Manufacturing performance is becoming more critical than ever to differentiation and overall business performance in specialty chemicals. It can either enable or sabotage efforts to deepen customer loyalty, as offering customer-tailored products and services through an increasingly complex operational footprint leaves no room for error in manufacturing. A lapse in either product quality or order fulfillment can seriously degrade a supplier’s reputation for reliability, undermining efforts to differentiate. Manufacturing performance is also a critical success factor for accelerating New Product Development and Introduction (NPDI), as market acceptance of even a “killer new product” can be compromised if manufacturing issues prevent it from being produced to consistent specifications or in a timely manner.

Many producers are finding that the status quo in manufacturing is not capable of meeting the growing demands of more customer-intimate business models. Current manufacturing practices simply drive too much variability in outcomes, provide too little visibility to important decision parameters and impose too much inflexibility to accommodate customer dynamics. Current practices are also too dependent on the knowledge and experience of long-tenured employees, many of whom are approaching retirement. As producers strive to more closely align with customers, they are coming to the realization that manufacturing practices honed during a bygone era are no longer adequate and must be transformed.

The imperative to elevate manufacturing performance to combat rising product, customer and asset complexity has spawned many “manufacturing excellence” initiatives throughout the industry. While these initiatives vary in scope, they are generally designed to enable more predictable operational outcomes, increase operational agility and drive cost efficiency through a combination of practice improvements and key performance indicator (KPI) management processes. A key objective of many manufacturing excellence initiatives is to not only improve manufacturing performance, but to increase manufacturing alignment to the end customer.

Common Challenges and Obstacles

Specialty chemical producers have made significant investments in automation and integration technologies over the past two decades to improve overall business performance. Enterprise resource planning (ERP) systems have automated many business and customer functions, with particular emphasis on transactional activities. Plant control systems have automated many foundational operations and safety functions, with particular emphasis on real-time activities. Both classes of systems were typically adopted via strategic, company-wide investment programs that emphasized standardized approaches across different plants and businesses. The successful implementation of both systems required substantial commitment and engagement from senior management.

While automation has certainly increased via these strategic investments, many core manufacturing functions still rely on non-automated practices, methods and tools. Manual procedures are pervasively utilized for plant start-ups, shutdowns and transitions between operational modes. Paper-based systems are commonly used to manage raw material recipes, operational targets and product specifications. Custom-developed spreadsheets are frequently leveraged to schedule production, dispatch orders and communicate directives. Extensive data gathering remains the dominant part of important activities, including troubleshooting, product tracking and quality certification. Poor visibility of final quality and performance indicators during the actual production process limits the ability to react to or even detect pending deviations.

Fulfilling the objectives of manufacturing excellence requires a level of performance that is simply not attainable by manual practices, ad-hoc methods and custom tools. A much higher level of automation is required than what typically exists for specialty chemical producers, especially for those manufacturing functions that have been largely untouched by prior ERP and plant control system investments. Successfully addressing this "automation gap" will be a key challenge for manufacturing excellence programs, and will require similar commitment from senior management as prior strategic investments.

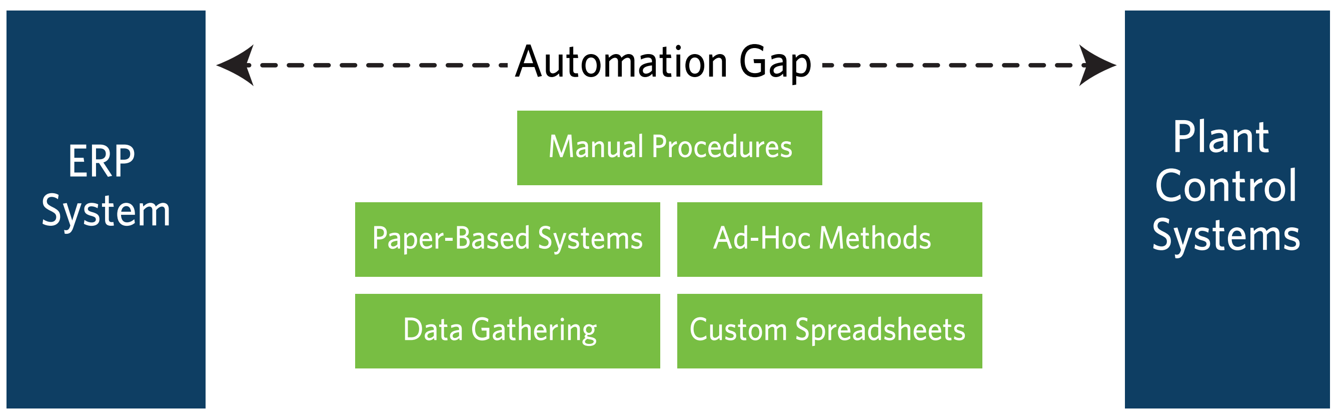
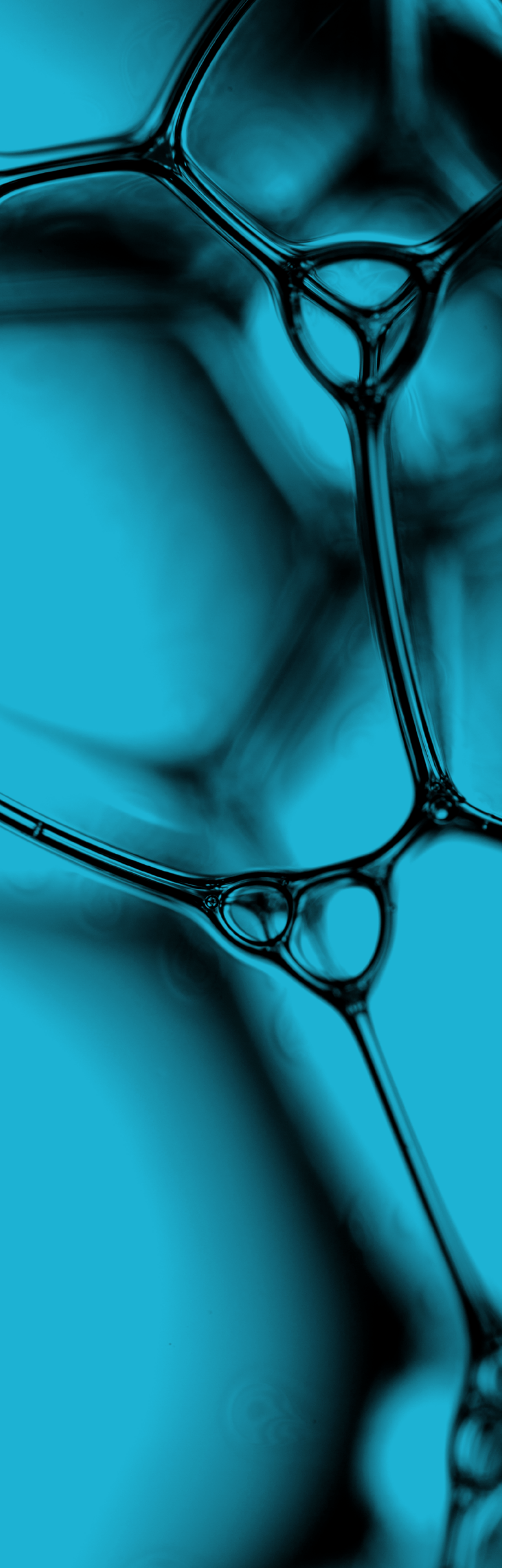


Figure 1: The Automation Gap



Manufacturing Excellence: Six Essential Levers

Manufacturing excellence is best viewed through the lens of the specific performance levers that are most impactful to the core business objectives of specialty chemical producers. These are the levers that, if successfully harnessed in a manufacturing excellence program, will deliver bottom-line results.

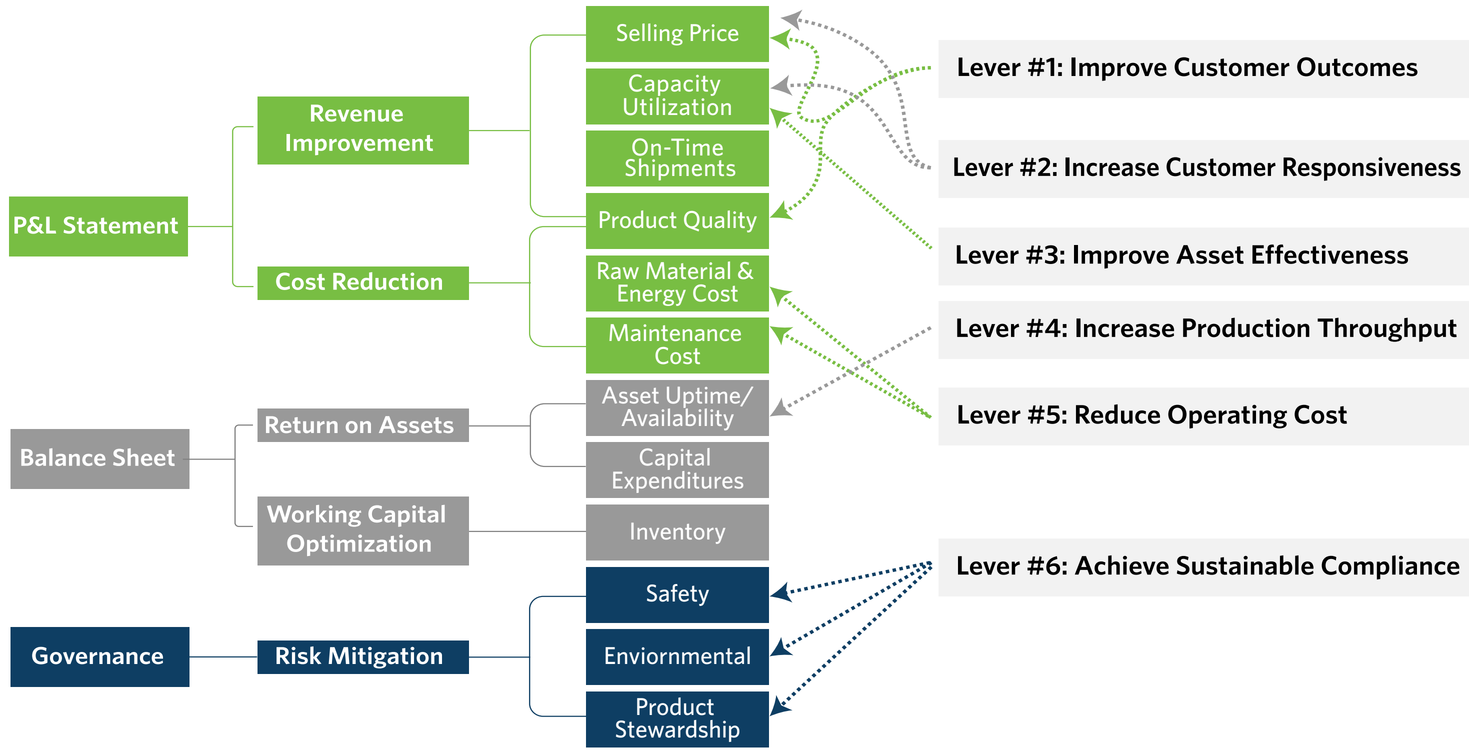


Figure 2: Six Essential Levers of Manufacturing Excellence

The following sections will explore how each of these manufacturing excellence levers can be exploited via the adoption of industry best practices, methods and tools to break the status quo and elevate manufacturing performance. Closing the automation gap via enabling technology will be an essential element of this transformation, and it will be reviewed in the context of best practices for each lever.

Lever #1: Improve Customer Outcomes

Customers for specialty chemical products are outcome oriented. The performance of those products in their end-use applications is the main reason customers choose one producer over another. For specialty chemical producers, this means that end-use product performance is the ultimate measure of success. Failure to consistently achieve it can negatively impact both selling price and customer loyalty.

A common problem for producers is variability in product quality that ultimately leads to variability in end-use product performance. The challenge of addressing this problem is increasing with product specifications becoming more complex: as both the number and types of specification parameters grow, so does the potential for variability in specification attainment. In many cases, lack of consistency in how a specification is achieved from one order to the next can be as bad as being off-specification in a key parameter.

Further exacerbating this problem is the fact that producers often manage many products in a single plant, some of which may be customer-specific variants that are not produced regularly.

There are several contributing factors that lead to variability in product quality. Most of these relate to variability in the underlying manufacturing process that is in turn caused by gaps in automation. For example, manual procedures and paper-based systems are still common for key activities such as raw material management, recipe execution and quality monitoring, leaving room for variability by person and shift, as well as human error. There can also be a limited ability to detect work-in-progress quality during the production process, particularly because of the many parameters that comprise the final specification and determine end-use performance. This lack of visibility and predictability of final product quality until post-production analysis is often compounded by a lack of understanding as to what process variations affect final product quality.

Leading producers have demonstrated a number of best practices to reduce quality variability and improve customer outcomes. ***Real-Time Quality Monitoring*** is a best practice that uses a combination of direct measurements and inferred values to continuously calculate product-quality KPIs in real time, often including leading indicators of impending quality deviations. This practice enables operations staff to detect quality problems during the production process and execute timely corrective actions. ***Golden Batch Profiling*** is a further enhancement that displays a real-time comparison of the current batch trajectory to that of a perfectly produced batch.

Procedural and Recipe Control is a best practice that involves automating the step-by-step sequence from when an order is dispatched to operations until the final product is produced. This automation is typically achieved with a manufacturing execution system that electronically manages all product recipes, operating procedures, production targets and product specifications to ensure consistent implementation every time a specific product is manufactured. These manufacturing execution systems typically interface with both ERP systems and plant control systems to enable a vertical integration from customer order to finished product lot.

Specialty chemical producers have achieved quality improvements of 10 to 20% by implementing the best practices described above, enabled by manufacturing execution, advanced process control and asset performance management solutions from AspenTech. The reduced variability resulting from these systems has directly contributed to improved outcomes for their customers.

Specialty chemical producers have achieved quality improvements of 10 to 20% by implementing Real-Time Quality Monitoring, Golden Batch Profiling and Procedural and Recipe Control.

Lever #2: Increase Customer Responsiveness

Specialty chemical customers are demanding – they want the right product at the right place at the right time. Their needs are never static and can often change on short notice. For specialty chemical producers, this places agility in manufacturing operations at a premium. Achieving a high level of customer responsiveness can be a powerful differentiator, elevating both selling price and customer loyalty. Not achieving high responsiveness can lead to both lost orders and lost customers.

Common problems for producers include variability in on-time order fulfillment and the inability to commit to short-lead orders, both of which are barriers to responsiveness. The challenge of addressing these problems is increasing as product and customer portfolios expand and manufacturing assets become more complex. The number of potential production scenarios can be in the hundreds, if not the thousands at many producer facilities, making it difficult to quickly determine how to fulfill customer demand. Variability in both manufacturing performance and customer demand further exacerbates these problems.

There are many contributing factors to these problems. Disconnects often exist between those who schedule manufacturing plants and the plants themselves in regards to key scheduling parameters, such as capacities, constraints and costs. Scheduling decisions are frequently made based on whiteboards, customized spreadsheets or other ad-hoc methods that are incapable of evaluating complex production trade-offs. Visibility of future available capacity, schedule gaps and pending conflicts is often limited to a day or two. The need for extensive data gathering and manual analysis often paralyzes decision-making, limiting flexibility to seize on short-term opportunities or accommodate customer dynamics. Relying on outdated, oversimplified business rules often leads to promising the impossible.

Leading producers have demonstrated a number of best practices to increase customer responsiveness. One of the most fundamental best practices, ***Model-Based Scheduling***, leverages models of manufacturing assets to automate the identification and evaluation of all potential production scenarios over time horizons that extend from weeks to months. Deployed via advanced decision support solutions, these models represent the full complexity and optionality of a manufacturing operation, including production rates, constraints, efficiencies, setup times, sequencing and site logistics. When implemented as part of a production scheduling process, model-based scheduling enables producers to fulfill customer demand in the most profitable way by utilizing the full range of production scenarios. ***Resource Sharing Optimization*** is a related best practice for finding the optimal way to share interchangeable equipment, resources and personnel between plant production lines.

Schedule Dispatch Automation, a best practice for conveying manufacturing directives, provides real-time details of scheduled process orders directly to manufacturing execution systems, including raw material requirements, recipes, operating procedures and production targets for each order. This practice enables more frequent schedule updates with fewer manual hand-offs between scheduling and manufacturing operations.

Specialty chemical producers have achieved an improvement of 8 to 12% in on-time order fulfillment by implementing the best practices described above, enabled by production scheduling and manufacturing execution solutions from AspenTech. The greater operational agility and flexibility resulting from these systems has directly contributed to increased customer responsiveness.

Lever #3: Improve Asset Effectiveness

Manufacturing assets, consisting of equipment, systems and resources, are at the heart of specialty chemical operations. How effectively those assets are utilized, whether measured by overall equipment effectiveness (OEE), capacity utilization or on-stream time, has a significant bearing on manufacturing and business performance. High asset effectiveness can enhance both customer satisfaction and profitability, whereas subpar effectiveness can divert customer focus and undermine competitiveness.

Common problems for producers include unplanned downtime and inconsistent equipment utilization, both of which degrade asset effectiveness. The challenge of addressing these problems is increasing as manufacturing assets become progressively more complex. It is not unusual for specialty chemical plants to employ multi-step processing where products build upon each other via different permutations of batch or even continuous processing steps. It is also not unusual for plants to consist of multiple production lines with varying levels of integration and dependency between them. Merely measuring equipment downtime and utilization can be difficult in this context, especially when start-ups, shutdowns and changeovers are considered.

There are several contributing factors to both unplanned downtime and inconsistent equipment utilization. The lack of detailed, quantitative understanding of the sources of downtime across a complex plant is a major factor. Another factor is the inability to detect or forecast impending equipment failures so that timely preventative actions can be implemented. The lack of visibility of equipment and system utilization, whether current, past or future, is also a contributing factor, as are ad-hoc production scheduling methods that fail to fully exploit asset capability.

Leading producers have demonstrated a number of best practices to increase asset effectiveness. One of the most fundamental is ***Real-Time KPI Monitoring***, which involves calculating important effectiveness parameters, such as OEE or resource utilization, and displaying to operations staff. ***Reliability and Availability Modeling*** is a best practice for evaluating the future effectiveness of an entire site or plant based on the reliability and availability of the individual elements that comprise it. The application of this practice enables producers to identify all losses in asset effectiveness, quantify which events/equipment are causing effectiveness losses and prioritize appropriate corrective actions.

Predictive and Prescriptive Analytics form the basis of a best practice to predict impending equipment failures and advise corrective actions to avoid or mitigate forecast failures. This best practice leverages current operational data and historical records, applying advanced pattern recognition with statistical and machine learning techniques. More sophisticated versions of this best practice use automated solutions that execute with minimal human involvement, continuously learning and adapting to operational changes and new failure conditions.

The previously discussed best practices of ***Model-Based Scheduling*** and ***Resource Sharing Optimization*** also contribute to improving asset effectiveness by exploiting all degrees-of-freedom in production scheduling.

Specialty chemical producers have achieved an improvement of 2 to 4% in OEE and on-stream time by implementing the best practices described above, enabled by asset performance management, manufacturing execution and production scheduling solutions from AspenTech. The increased visibility, understanding and predictability resulting from these systems has directly contributed to improved asset effectiveness.

Lever #4: Increase Production Throughput

Specialty chemical producers are constantly under pressure to extract higher volumes from their existing manufacturing plants. Increasing production throughput with little to no capital investment not only drives incremental revenue growth, but also frees up available capacity for new products. It is an important element for both manufacturing and business performance improvement.

Unplanned downtime, as discussed in the previous section, is a common problem faced by producers – reducing it effectively increases production throughput. Producers encounter problems beyond unplanned downtime, however, that limit their ability to increase throughput. In batch production processes, it is common to experience variability in the time required to produce a batch, typically known as batch cycle time. In continuous processes, it is common to experience variability in production levels on a day-to-day and even hour-to-hour basis. Variability in both batch and continuous production prevents "best demonstrated" throughput from being consistently achieved.

There are many contributing factors to production variability in specialty chemical plants. Manual procedures are often applied for start-up, shutdown and process transitions. Paper-based systems are frequently used for recipe management and execution. Effective indicators of batch progress-to-completion are often lacking during the actual production process. Process disturbances occur frequently, beyond what can be effectively neutralized by existing plant control systems. When production upsets inevitably arise, troubleshooting efforts are often delayed by the need to gather and analyze data from disparate sources.

Leading producers have demonstrated a number of best practices to reduce production variability and increase production throughput in both batch and continuous specialty chemical processes. ***Real-Time Process Monitoring*** uses a combination of direct measurements and inferred values to calculate batch progress towards completion, enabling operations staff to minimize batch cycle time. The previously discussed best practice of ***Golden Batch Profiling*** illustrates the trajectory of a current batch relative to that of a perfectly produced reference batch, enabling batch-to-batch consistency. ***Procedural and Recipe Control***, also discussed previously, enables more consistent execution of start-up, shutdown and transition activities.

Advanced Process Control (APC) is a best practice for minimizing variability in continuous processes by holistically managing all of the complex, multi-variable interactions that occur across an entire process unit. When implemented on top of an existing plant control system, APC rejects disturbances much more effectively than control systems alone, enabling production rates to be consistently maximized near physical constraints.

The previously discussed best practice of ***Predictive and Prescriptive Analytics*** can also be applied to identify emerging process upsets that are invisible to operations staff based on prior event "fingerprints," enabling corrective actions to be prescribed to mitigate or prevent upsets.

Specialty chemical producers have achieved production increases of 3 to 5% by implementing the best practices described above, enabled by manufacturing execution, advanced process control and asset performance management solutions from AspenTech. The reduced process variability and increased production throughput resulting from these systems has contributed directly to business growth objectives.

Lever #5: Reduce Operating Costs

Cost competitiveness is becoming progressively more important for specialty chemical producers as they fight to defend margins in an era of increasing competition. Finding ways to continuously reduce operating costs by managing its major controllable elements – energy consumption, raw material efficiency and maintenance effectiveness – is vital to manufacturing performance improvement.

A common problem for producers is that the performance of these major controllable cost elements varies substantially, whether from month-to-month, day-to-day or batch-to-batch. For example, specific energy consumption – the energy required to produce a unit of product – can vary by shift or even operator. Raw material efficiency, frequently measured as product yield, feedstock conversion or a combination thereof, can vary in a similar

manner. Maintenance costs can deviate significantly if unexpected breakdowns drive high percentages of disruptive, reactive maintenance activities. For all of these problems, the challenge is unfortunately growing as the number of products increase and assets become more complex.

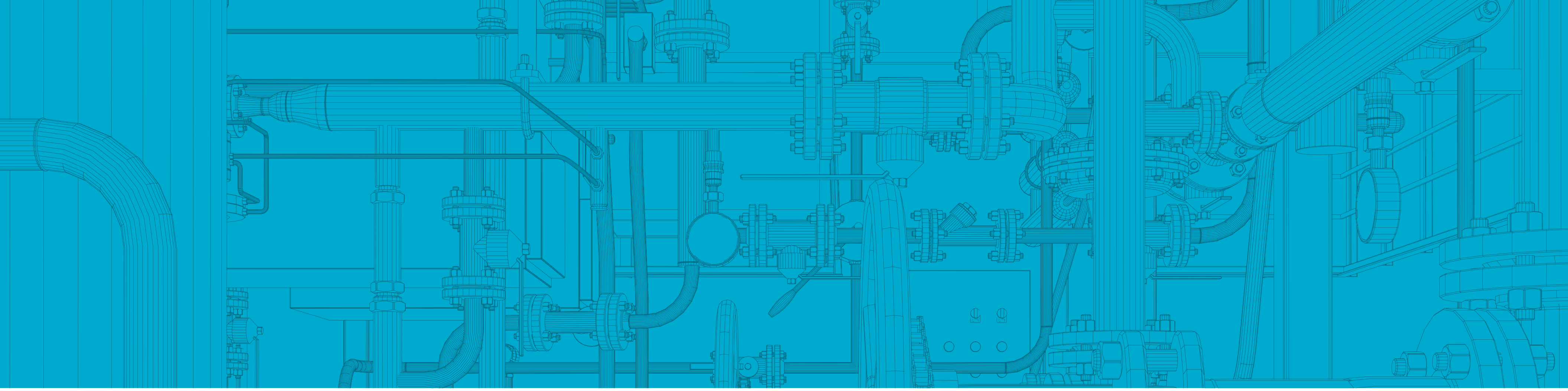
A major contributing factor to cost performance variability is the prevalence of manual procedures and paper-based systems for raw material management, recipe execution and process transitions. A second major factor is the lack of effective work-in-progress yield and energy indicators during production. Process disturbances that cannot be effectively neutralized by existing plant control systems are yet another factor, as is the inability to detect or forecast impending equipment failures or major upsets.

Leading producers have demonstrated a number of best practices to reduce operating costs in specialty chemicals manufacturing. ***Procedural and Recipe Control***, a previously discussed best practice, enables both raw materials and energy to be utilized on a more systematic, consistent basis. ***Real-Time Energy Monitoring*** provides continuous visibility of energy consumption in an overall process, as well as its physical components and production steps, enabling operations staff to avoid overconsumption relative to targets. The previously discussed best practice of ***Golden Batch Profiling*** illustrates yield and energy performance trajectory of a current batch relative to that of a perfectly produced reference batch, enabling batch-to-batch consistency. ***Batch KPI Reporting*** provides a detailed, post-production view of all cost performance attributes for a batch, enabling cost variance analyses against production standards to support continuous improvement.

Advanced Process Control (APC), a previously discussed best practice for continuous processes, enables increased yields and reduced energy consumption by minimizing variability caused by process disturbances.

Predictive and Prescriptive Analytics, as discussed previously, can be applied to detect impending equipment failures so that timely preventative actions can be implemented to avoid both failure and associated maintenance costs. It can also be applied to identify emerging process upsets so that elevated raw material and energy costs can be avoided through timely corrective action.

Specialty chemical producers have achieved lower operating costs of 2 to 5% by implementing the best practices described above, enabled by manufacturing



execution, advanced process control and asset performance management solutions from AspenTech. The increased visibility of cost drivers and reduced variability in cost performance delivered by these systems has directly contributed to improved cost competitiveness.

Lever #6: Achieve Sustainable Compliance

Compliance has always been a core business tenet for specialty chemical producers, spanning environmental, safety, product stewardship and more. In recent years, the ability to document procedural compliance in manufacturing has been a growing need, whether driven by government regulations, end-use market requirements or specific customer requirements. Documented procedural compliance is a driver of customer satisfaction, and is rapidly becoming a pre-requisite to participate in many market segments.

A common problem for specialty chemical producers is that procedural compliance activities are both time consuming and cumbersome, generally requiring compliance-dedicated staff. Another problem is that the extensive time needed to research, validate and document procedural compliance often delays batch releases to customers, negatively impacting both operational agility and customer responsiveness. If a customer files a product complaint or mandates a general audit, further time must be invested to investigate, resolve and comply. All of these problems are exacerbated by the combination of expanding product portfolios and frequently inconsistent manufacturing execution.

Contributing factors that impede compliance efforts include manual procedures that are unenforceable, ineffective procedural tracking, manual data entry, paper-based operator logs and a general lack of audit mechanisms. The need to gather information, records and data from multiple disparate sources is a further contributing factor. Of course, the automation gaps that lead to variability in manufacturing performance are by extension contributing factors.

Leading producers have demonstrated a number of best practices to streamline compliance activities. ***Electronic Batch Records*** is a best practice for capturing all information associated with the production of a specific batch, including the actual procedure and recipe implemented, operator control actions, operator logs, quality tests, specification attainment, process data, and digital signatures. The actual operational information is then consolidated into a single batch record and compared electronically to the established procedures, parameters and specifications to document compliance.

Product Genealogy is a best practice for tracking a product through the entire span of the manufacturing process, from raw materials to the final packaged product. In this practice, finished product lots are "tracked and traced" backwards through the production process, identifying the specific raw material lots, batches, equipment, resources, sequencing and packaging that were used to manufacture the product lot. This practice enables producers to rapidly investigate customer complaints, as well as respond to audits and recalls.

The previously discussed best practices of ***Procedural and Recipe Control, Golden Batch Profiling*** and ***Batch KPI Reporting*** also contribute to more effective compliance by improving manufacturing consistency.

Specialty chemical producers have successfully reduced the burden of compliance, while simultaneously achieving faster product releases with fewer errors by implementing the best practices described above, enabled by manufacturing execution systems from AspenTech. The streamlined compliance enabled by these solutions not only facilitates customer responsiveness, it transforms compliance into a sustainable activity to support business growth in an era of increasing regulation.

The Bottom Line

Specialty chemical producers are at a crossroads. The manufacturing practices that evolved over an era of lower complexity are simply not capable of meeting the growing demands of more customer-intimate business models. If producers intend to sustain differentiation and business performance, they need to shatter the status quo of manual procedures, ad-hoc methods, paper systems and custom spreadsheets in manufacturing. Producers need to transform their manufacturing practices to enable greater agility, more predictable outcomes and cost efficiency, while simultaneously accommodating a shifting workforce that will be less experienced than their predecessors.

The ***six essential levers*** can be viewed as a roadmap for specialty chemical producers to achieve manufacturing excellence goals and drive step-change improvements in manufacturing performance. Core to each of the six levers are demonstrated best practices that can deliver meaningful and measurable benefits in the form of improved product quality, more on-time orders, increased utilization, higher production, lower operating costs, and streamlined compliance. Technology is an essential enabling element for all of these best practices and is critical to closing the automation gap that exists for many core manufacturing work processes.

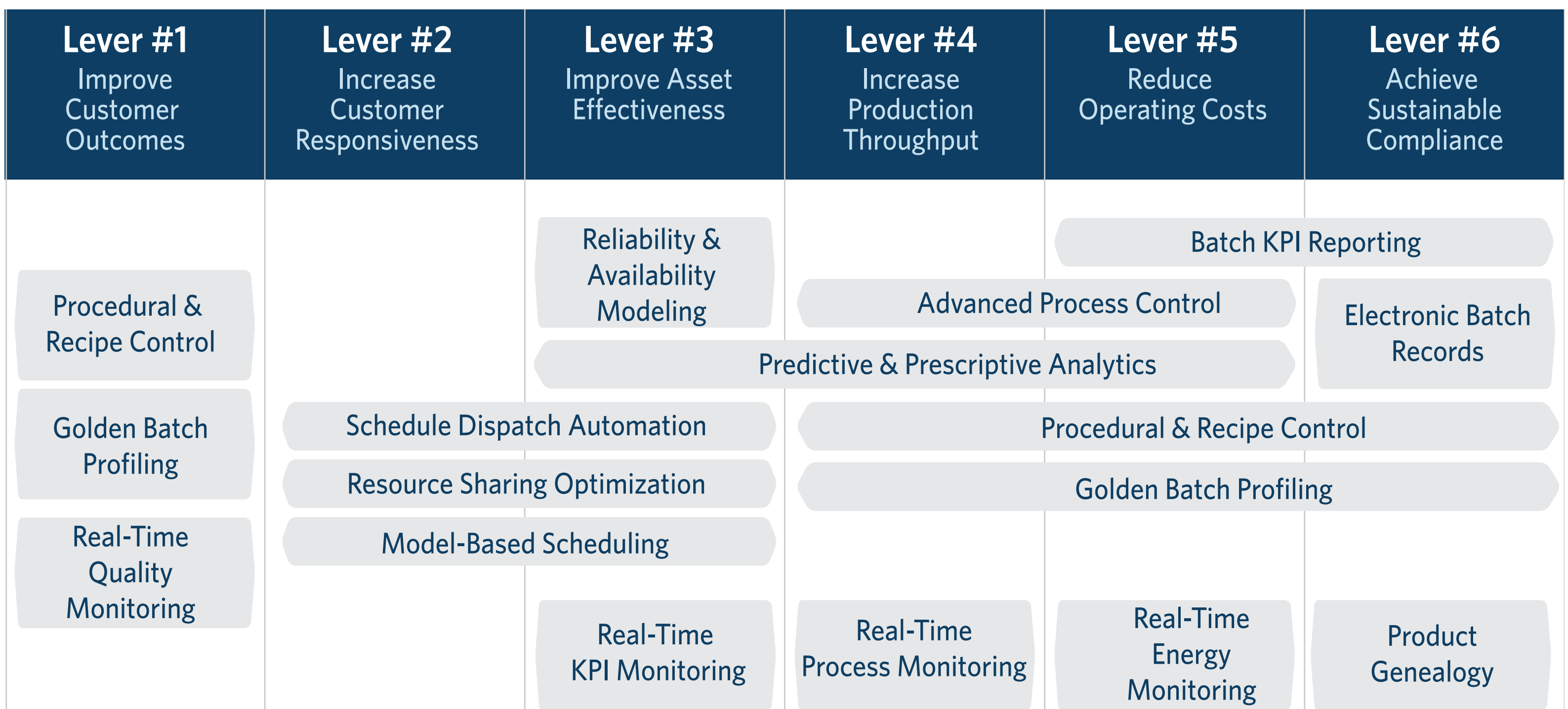


Figure 3: Six Essential Levers of Manufacturing Excellence with Best Practices

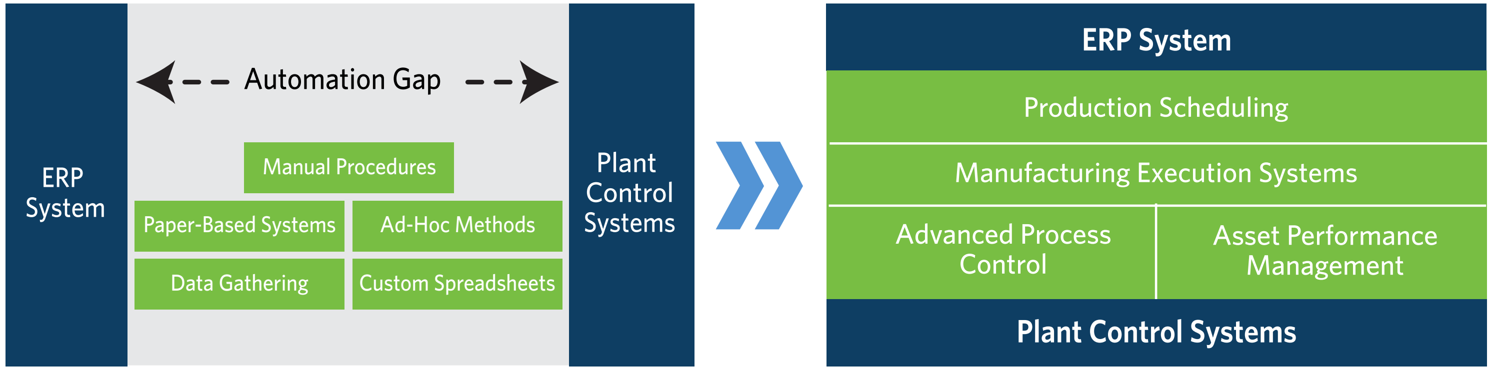


Figure 4: Closing the Automation Gap

The automation gap that persists at many specialty chemical producers remains an impediment to transformation. This is acknowledged by the phenomenon known as "Industry 4.0," which in its chemical industry variant focuses substantially on closing this automation gap via "digitization and integration" technologies. Successfully addressing this automation gap will clearly be a critical success factor for manufacturing excellence programs, as well as for manufacturing performance improvement in general. It will require the same level of commitment, focus and engagement from senior management as prior strategic investments in ERP and plant control systems.

AspenTech has been helping chemical producers establish best practices and achieve their business goals for decades with its comprehensive manufacturing portfolio spanning production scheduling, manufacturing execution, advanced process control and asset performance management. Leading producers such as ***Dow Chemical, BASF, DuPont, INEOS, SABIC***, and ***Evonik*** rely on solutions from AspenTech to improve manufacturing performance.

With current business trends, manufacturing excellence will likely remain a strategic imperative for specialty chemical producers. It will be the key to mitigating the growing complexity of specialty chemical manufacturing, while enabling higher customer alignment and faster innovation. How effectively producers embrace it will have a material impact on their customer satisfaction, market share and profitability in an increasingly competitive market.

Technology That Loves Complexity

AspenTech is a leading software supplier for optimizing asset performance. Our products thrive in complex, industrial environments where it is critical to optimize the asset design, operation and maintenance lifecycle. AspenTech uniquely combines decades of process modeling expertise with machine learning. Our purpose-built software platform automates knowledge work and builds sustainable competitive advantage by delivering high returns over the entire asset lifecycle. As a result, companies in capital-intensive industries can maximize uptime and push the limits of performance, running their assets faster, safer, longer and greener.