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Plant-to-Enterprise Integration:
Foundation for MES/MOM Payback

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Cambashi researches the use of Information and Communication Technology (ICT) in industry. Our goal is to understand

- the business reasons that drive ICT investment decisions,
- the technology that addresses these issues,
- the market mechanisms that bring users and vendors together, and
- the impact of deployment of applications and infrastructure.

The ideas and opinions expressed in this white paper are Cambashi's own, based on our continuous programme of independent research. We wish to thank SAP for sponsorship of production of this document, enabling us to communicate our analysis in this format.

Executive Summary

Manufacturers must leave nothing to chance. Business processes must be reliable and based on accurate and timely information. Any gaps in data can allow errors in mission-critical processes, and result in quality, cost and delivery problems. These, in turn, can lead to loss of customer confidence and result in negative financial consequences.

Gaps in data have typically occurred within plant operations and at the interface between the factory and the enterprise. Manufacturers now realize that to fill the data gaps requires

- Coherent , integrated information systems spanning the whole plant
- Two-way information flows between production plants and the enterprise

In short, manufacturers need Manufacturing Execution System (MES) or Manufacturing Operations Management (MOM)[1] systems on an enterprise scale, and with enterprise integration. Research by Cambashi and others shows that more and more companies have recognized the need for MES.

MES/MOM is a maturing market, where commercial off the shelf products generally perform well. However, most of the business drivers for MOM investment also demand plant-to-enterprise (P2E) integration. To date, P2E integration has not been mature, reliable, or clearly articulated. This has led to project-specific P2E that often has a negative effect on the ROI of the systems it integrates.

Historically, the challenge has been that plants have unique needs, and this works against the enterprise information systems (IS) objective to lower cost through standardization. A plant's specific issues may shift over time, particularly with continuous improvement efforts. So each plant needs to re-configure information systems to support those changing needs. This has historically prevented effective standardization of MES and P2E integration across the enterprise. As a result, IS had to deal with specialized integration of products from a number of vendors or simply not attempt a complete integration of these systems.

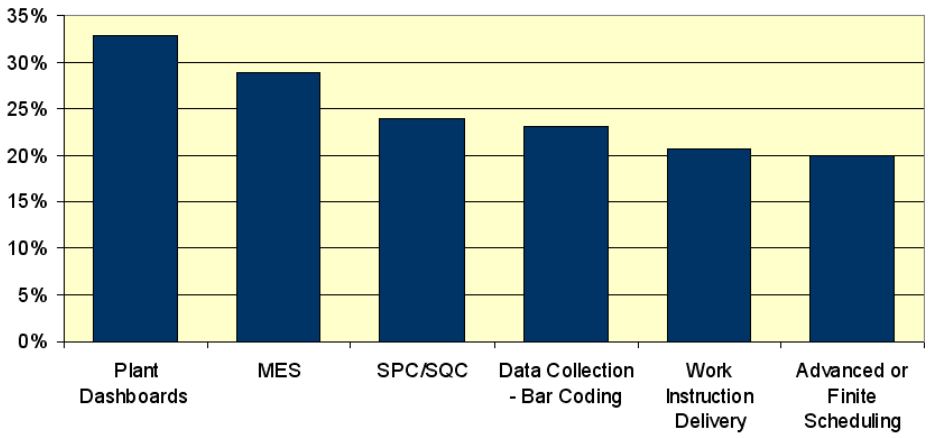
Fortunately, effective and robust plant operations systems with assured information flows to and from the enterprise are now increasingly achievable and sustainable. Proven MES/MOM software that is configurable for every plant has been available for some time. Now standard P2E integration frameworks are emerging in which these plant-specific applications can operate as an effective enterprise information system. The keys are to separate data flows from the sources of data, and to have configurabe operational processes at the MES/MOM layer with the ability to pull enterprise data as needed for each process.

The result is that plant operations can each be unique, while IS gains a stable enterprise-wide environment for the long term. Plants can gain competitive advantage with both local and enterprise information support. Information systems can consistently manage end-to-end business processes spanning the enterprise. Both plants and enterprise can make improvements and change systems without breaking the integration. Everyone wins.

[1] Cambashi uses MES and MOM interchangeably. While some software providers are trying to paint MOM as a next generation of MES, we believe that a natural market evolution is in process, and that buyers are now learning the value of these systems, which they may call by either term.

MES/MOM is rising in importance

Plant operations can determine the quality, timeliness, and profitability of products. Reliably doing the right things the right way at the right time inside the plant is based on more than experience, gut feel and intuition. To enable continuous improvement, companies need a complete, in-context view of what is supposed to happen – and what actually happens – in a factory or a network of factories. In short, lean, six sigma, and related practices can and must fully leverage integrated MES/MOM systems.



Source: *MESA Metrics that Matter: Uncovering KPIs that Justify Operational Improvements*

Figure 1: MES/MOM functionality, whether in an integrated system listed as separate functions, are commonly in manufacturers' software investment plans.

Cambashi research, in conjunction with MESA International, shows strong interest and growing investment in MES/MOM systems. (See Figure 1)

Executives in Operations, IS (information systems), finance, product design, and even sales and procurement are beginning to appreciate the value these systems can offer.

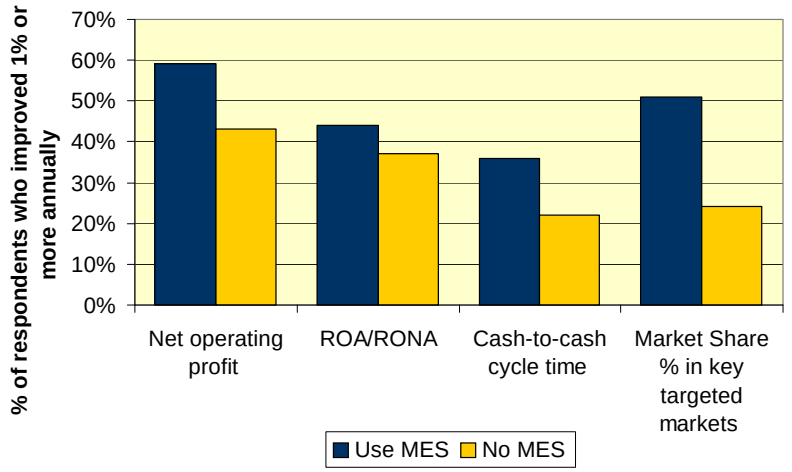
- ***Operations*** is the most obvious beneficiary, as MES/MOM provides them a coherent view within and across plants. These systems are specially designed for the conditions and staff commonly found in factories. MES/MOM can actually drive or enforce best practices to improve reliability and predictability.
- ***IS*** correctly sees MES/MOM as a way to "connect the dots" and paint a fuller picture of actual operations. MES can provide the data enterprise applications and business intelligence systems need to provide accurate transactions, plans and views on which to base decisions.
- ***Finance*** knows that plants are a major determinant of both costs and revenue-generating capacity, so they want accurate information for current performance and the ability to set realistic financial plans and forecasts.

- ***Product design*** needs feedback from the plant to drive innovation, and an assurance that engineering changes will be implemented as intended.
- ***Sales*** is seeking differentiation. Delivering high quality products on time is the hurdle just to compete. Companies that can deliver complete documentation of product and component origins, and provide customers with confidence-building insight into operations are likely to be preferred.
- ***Procurement*** knows that the true test of a supplier is in not just price and on-time delivery, but how well their materials perform in the particular products and production environment.

The plant-wide information that MES/MOM manages is core to what these stakeholders are trying to achieve: product innovation, supply chain responsiveness, product quality, and effective asset management. Good outcomes on all of these fronts are core to profitability and competitiveness.

Despite all of the value, making MES/MOM a truly standard enterprise application has been a major challenge, since every factory is different. Many companies have diverse plants running different products through various makes and models of equipment. Even plants that seem nearly identical may have different workforce, climate, and operating conditions. While there are similarities, each plant is unique, so MES/MOM products must be flexible to accommodate best practices and continuous improvement.

Commercial off the shelf (COTS) MES/MOM software that meets a manufacturer's needs is generally available today. More of the companies using MES have made improvements to operations and financial key performance indicators than those that don't. (See Figure 2). Visibility and control over plant operations is often the deciding factor in a manufacturer's health. This puts pressure on competitors to improve as well. As a result, MES/MOM enterprise-level selections and rollouts are becoming increasingly common for manufacturing companies worldwide.



Source: *MESA Metrics that Matter: Uncovering KPIs that Justify Operational Improvements*

Figure 2: Companies using MES/MOM are more likely to have improved against key business performance metrics.

Why P2E integration is a hot topic

The value that various departments envision from MES/MOM depends on having plant-to-enterprise (P2E) integration. P2E integration enables the next step in effectiveness for supply chain, product design, customer-driven sales and marketing, and financial success.

MES sits at the intersection of the supply chain process and the product innovation process. (See Figure 3)

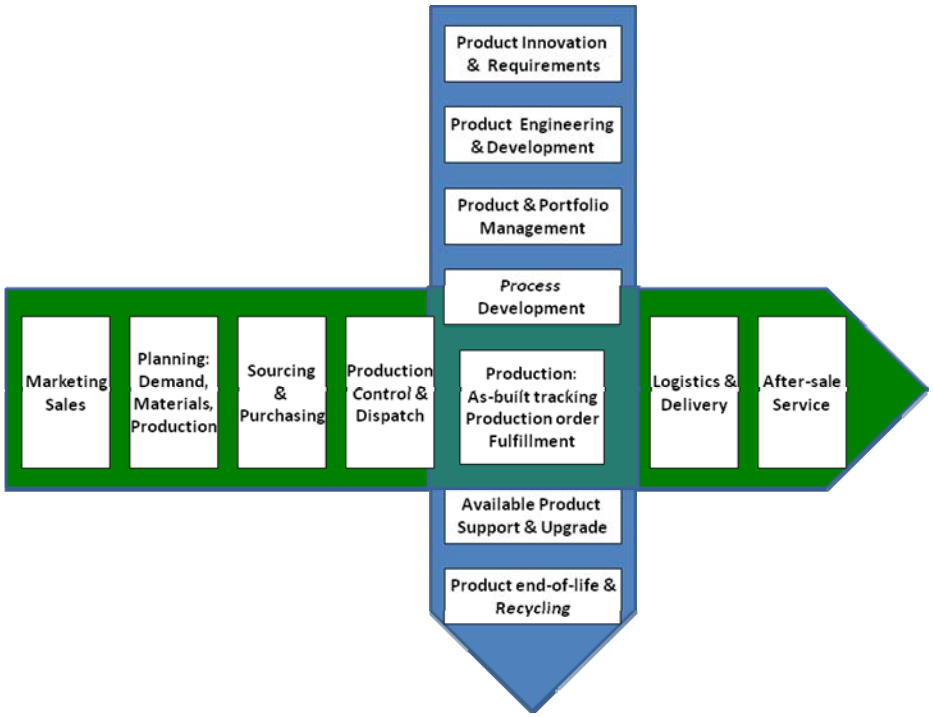


Figure 3: Production sits at the core of both product introduction and innovation or PLM as well as the supply chain order execution cycle.

Visibility of the plant operations to the rest of the enterprise is one of the main reasons that P2E is important. Most companies cannot accurately see

- the real issues of manufacturability for new or re-designed products
- the performance of suppliers' materials
- the state of expensive capital assets during production
- the progress of orders through the plant

This is true not only in plants with paper-based or basic systems, but also in those with MES/MOM that is not integrated into other enterprise applications.

Synchronization of activities in volatile conditions is also driving P2E investments. In today's environment, supply and demand can easily become mismatched. The production floor is where orders are filled, and where supplied materials enter a company's value stream. Product mix through the plant is often high and variable. This is very difficult to manage without a coherent plant-wide system. Being at the center of the supply chain and innovation processes, MES can provide information for the enterprise – but only if it's integrated.

Unfortunately, many companies' need for visibility and control across the plant has been so acute that they have implemented an MES/MOM without a master plan. Many MES implementations are in a single plant, without good integration to the enterprise resource planning system (ERP). This becomes a major roadblock to delivering value. Those P2E information flows are required to fulfil the needs that enterprise functional stakeholders have, as well as top operations executives with a multi-plant purview.

The big benefits of an MES/MOM investment come through integration to other applications such as ERP, product lifecycle management (PLM), customer relationship management (CRM), supply chain management (SCM), enterprise asset management (EAM), and supplier relationship management (SRM). The benefits accrue in a wide range of areas for a manufacturing business:

- Financial benefits are suggested in Figure 2, but having visibility into and control over the core production assets, both fixed such as equipment and variable such as inventory can dramatically shift both costs and revenue generation performance.
- Track and trace through the supply chain is increasingly important not only for regulatory compliance, but also for product quality assurance. While the plant information is essential, a complete record also requires information from suppliers and outsourced partners, integrated into a coherent product history record or genealogy.
- Order fulfillment benefits from P2E visibility for status and synchronization to balance activities with demand and supply. Fulfillment performance – from timeliness and reliability to cost and quality of products – rests largely in production and configuration for many complex products manufacturers.
- Product innovation success is determined not only in the engineering department, but also in the factories where designs become revenue-generating products. Ensuring the flow of as-designed and as-built information is just one aspect of this; design for manufacturability and concurrent engineering are others that P2E can enable.
- Productivity throughout the enterprise can improve with smooth information flows to and from the plant. Many companies currently spend time gathering at or guessing at production rates, quality, and progress, because data does not flow.
- Scorecards are a foundation of management by fact. MES/MOM can enable accurate performance views of plants and suppliers. It also enables the company to benchmark itself to avoid surprises or customer misunderstandings.
- Asset exploitation for maximum revenue at minimum operating costs is a core metric of financial success. This return on assets (ROA) relies heavily on having an accurate and up-to-date view of the equipment and facilities in factories.

For most companies, steady performance means falling behind, so they have adopted improvement initiatives that also need information support. Initiatives such as lean, perfect order, total quality and compliance, supply network collaboration, sustainability or green, and certainly real-time enterprise all either rest on or benefit significantly from P2E integration.

Integration as foundation vs. afterthought

Based on its benefits, P2E integration seems like a no-brainer, but is not nearly as mature as MES/MOM. With a lack of standard approaches, P2E integration has actually been challenging and risky. As a result, many companies move forward with MES/MOM implementation without a clearly defined path for P2E integration.

To date, P2E integration has often been an afterthought. With both MES and ERP implemented independently, companies can experience a range of problems when they do get to the point of a P2E integration project. These challenges include:

- **Data reconciliation:** While most companies have achieved a master record and format for enterprise data, factoring in detailed plant data can result in a regression to complex environments with duplicate data that must be translated between incompatible formats.
- **Implementation re-thinking:** To accommodate MES/MOM decisions that did not factor in enterprise information flows or ERP capabilities, companies must sometimes step back and re-implement. Realistically, MES and ERP often overlap, and making decisions about system of record and best practice information flows up front is critical.
- **Upgrade barriers:** P2E integration usually breaks when one system is upgraded, so companies may avoid upgrades and thus not gain benefits from new functionality, or they pay for regular fixes to the integration.
- **Technical challenges**: Error checking, reliability of data transfers, and other technical considerations are easier to address before implementation than after.
- **Impediments to process change:** Core systems and integration changes to accommodate business process change may be difficult or impossible. As with upgrades, this could discourage improvement and reduce opportunity for competitive advantage.

However, as in many other things, it pays to think globally first. Some companies are doing that by leveraging a standard for Enterprise-Control System Integration, ANSI/ISA-95, also available as IEC/ISO 62264. This standard includes a model that outlines elements of MES/MOM functionality (Layer 3 of the model) as well as two-way information flows with enterprise systems (Layer 4 of the model). This standard provides a common conceptual starting point and terminology that enables all of the concerned stakeholders to analyze what functions and data flows are desirable over the lifecycle of the integrated systems.

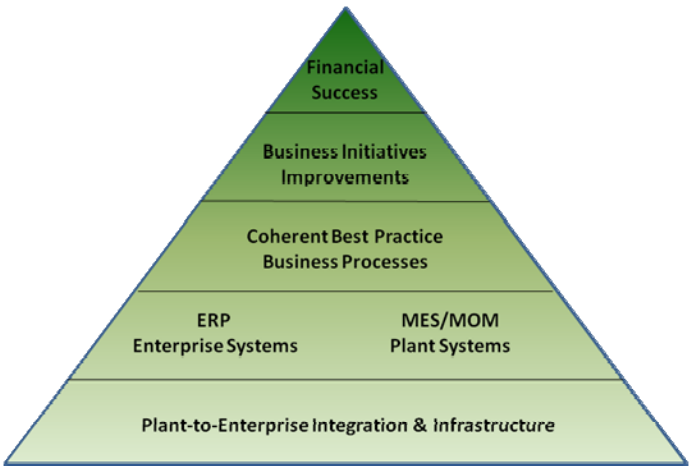


Figure 4: To achieve financial success, companies need information systems based on strong integration and infrastructure. Applications implemented based on an integration scheme are more likely to achieve business goals.

Whether using the model or a unique view, P2E integration architecture should be considered prior to a focus on detailed application functionality. (See Figure 4) This is in part because the plant floor is radically different than the office. The timeframes,

system users, data types, and consequences are different for MES/MOM than for ERP. So a specially-designed P2E integration architecture is the best way to ensure that both systems contribute to creating those value-adding data flows.

MES/MOM applications must connect with sometimes massive quantities of real-time data, and must be up and running whenever the operation is, which can be 24 x 7. Factories can be dirty, noisy, and require that employees wear protective clothing. The users are not at a quiet desk, and working with data is not the major goal of their jobs – making products is.

P2E integration can also lead to greater cooperation between IS teams and manufacturing and plant engineering groups. At the P2E junction, this broader understanding of the rationale for both manufacturing and IT decisions is critical. IS brings disciplines for low-cost systems procurement, implementation and maintenance into manufacturing, and the manufacturing team can instill an understanding of true mission-critical, no-downtime information processing to IS. Our research shows that those working toward this convergence between plant engineering and IS are seeing significant benefits.

These issues may explain why some software companies are beginning to provide end-to-end solutions, with P2E provided as a standardized part of the product offering and support contract. Such a strategy takes much of the above burden from the implementation itself. This end-to-end business process approach to delivering P2E as integral to applications is likely to continue to gain traction in the vendor as well as end user community.

Plant-IS balance: flexible yet standard

How do you balance the need to keep production running well with the desire to keep IS costs low? Tension between plant operations and IS teams tends to be around this question. Plants want the flexibility to tailor and improve mission-critical manufacturing processes and IS knows best practice is to standardize, simplify and lower the ongoing cost of information systems.

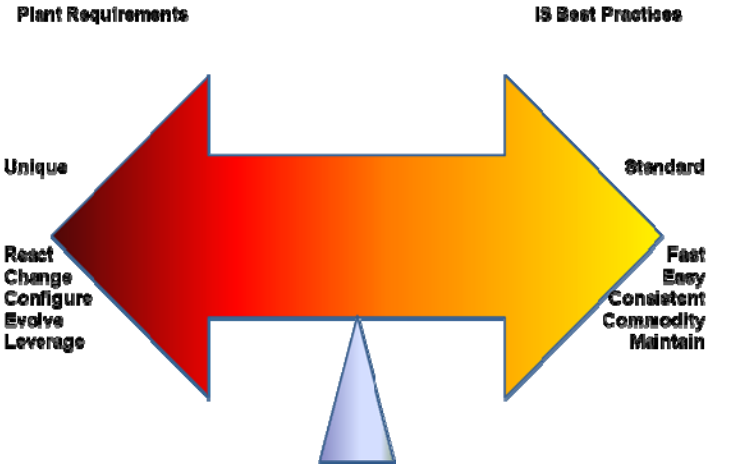


Figure 5: While plants need the ability to support unique situations and evolving best practices, IS will always drive toward standardization. Finding this balance creates tension, but it is increasingly possible to satisfy both parties.

With the maturing of MES/MOM and increased understanding of P2E integration, a new approach has emerged. This combines a flexibility to tailor the MES/MOM and business workflows with a standardized approach to the core P2E integration. This approach recognizes that it's not beneficial to sacrifice plant-specific needs, but also that integration can be a larger investment than applications functionality, with escalating costs over time if not managed carefully.

We'll examine the two foundation pieces required for this balance to work.

Plant Flexibility: The MES/MOM itself must be configurable for many different environments, with a wide array of functions for the plant. The MES/MOM should be proven in various situations, and have deep application capabilities to ensure that the plant personnel see value. Some companies will have plants that don't need full-blown MES/MOM, but rather a way to facilitate simple information flows to support key processes and decisions. Yet other plants will need both MES/MOM and special workflows to support specific business processes that deliver a business edge. This array of appropriate capabilities that each plant can leverage helps ensure continuous improvement and competitive advantage.

P2E Standardization: While many companies have achieved some integration for single plant success, few have yet embarked on multi-plant and enterprise-style rollouts. This is where the standardization of integration has the greatest opportunity to pay off. Ideally, this integration ensures master data is not replicated; so each data element (such as inventory or assets) is housed in its appropriate environment of ownership.

Overlapping master data creates complex relationships for P2E so P2E design needs to take into account the data's relationship with the system of record and ensure simplicity of ownership. Naturally, transactions flow between systems; for example, incoming orders and backflushing of materials. Integration should accommodate synchronous and asynchronous processing, so that information flows in a timely fashion (not just overnight batches) yet when the ERP is down for routine maintenance, the MES will support a plant even if it runs 24 x 7. Even with standardized

integration, not all data should be treated the same way within the same integration, since data behavior is different. For example master data and transactional data and must be treated differently. Ideally, the interface is coordinated with software releases, so upgrades of one system include needed upgrades to the integration. When these topics are considered, standard P2E integration facilitates faster ROI, and lowers cost to maintain P2E integration as well.

The result of this style of integration is reliable information support for end-to-end business processes. The critical processes that depend on P2E integration and will thus benefit include:

Traceability: more automated data collection and formatting for end-to-end product genealogy for both regulatory compliance and supplier management

Order fulfilment: ensuring the plant always has the right mix of production orders, repetitive or planned orders, and service orders; and that critical translations from enterprise to plant such as order splits and merges and engineering changes are reliable

Inventory accuracy: understanding what materials are reserved, backflushing for lean, confirming components, and reporting details on scrap, returns, material classification, binning or problems; and making unit of measure conversions from stores into production all matter to the supply chain

Asset Leverage: having a full view of equipment downtime – scheduled and unscheduled can greatly increase a company's ability to improve return on assets

Quality & compliance: streamlining processes for checking operator certifications, quality notifications, batch data collection, and overall equipment effectiveness (OEE) reporting

All of this has been possible before, but not necessarily with the combination of plant-level responsiveness plus IS infrastructure consistency. Not surprisingly, SAP, as the first top-tier ERP provider to acquire an established and robust MES/MOM product, is paving this path. With control of both enterprise and plant software applications, SAP can offer a standardized integration framework that works not only when first implemented, but also and longer term through upgrades. This takes the responsibility of integration off the buyer and puts it in the hands of a single software provider. This strategy not only allows for plant-based MES with enterprise integration control, but also treats P2E as part of the overall software portfolio, delivering end-to-end business processes that are subject to standard maintenance, support and upgrades.

Clean and productive P2E integration rests on having logical ways for both enterprise and plant data to feed effective end-to-end business processes. The key is to eliminate data translation, duplicate data and the resulting reconciliation needed between systems. One sound approach is to configure processes at the MES/MOM level, and ensure that all data to support the processes is available from other enterprise system functions through the P2E integration scheme.

In this environment, plant business processes are outlined in advance, and leverage P2E integration functions to bring in appropriate data from ERP on inventory, suppliers, and logistics and from PLM on designs and specifications, for example. Separating out the end-to-end business process from the sources of data needed to support that process is one way to keep production flexible and integration predictable.

Integration is a foundation for payback

Many manufacturing companies are in a fight for their financial lives. They have adopted initiatives from perfect orders to low cost of quality, to lean no-waste operations, to regulatory compliance via track and trace, to maximum asset performance, and many others. In this environment, the plant's status as an important provider of information is clear. MES/MOM has become a critical IS investment for many companies.

However, implementing MES in one plant or all of them does not guarantee good outcomes, particularly over the long term. To gain full benefit from MES/MOM, companies need to have P2E integration. Critical business processes flow through not just the plant, but the entire enterprise and its ecosystem of partners. Plant-to-enterprise information flows support some of the highest impact business initiatives.

Even manufacturers that invest in MES/MOM and integrate it may struggle to maintain competitive advantage if P2E integration is an afterthought. As mentioned before, companies should determine which system will own the master data for inventory, assets, and other items based on the master data's relationship with the system that creates it. Failing to consider this can compromise P2E integration success. The integration strategy must also ensure that information will flow to factory operations even when the ERP is down for maintenance. Most challenging of all is an approach to P2E integration that will endure over time. The change inherent in continuous improvement programs, along with systems upgrades and version changes, means that software on both sides will inevitably evolve, which can easily render the integration work ineffective or completely inoperable.

Total cost of ownership of P2E integrations has been hard to predict. Manufacturers have found to their dismay that the cost of these integrations is likely to rise, particularly when either plant or enterprise systems were upgraded or business processes improved. Standard P2E integration counters this and keeps costs lower and more predictable over time.

Until recently, plant operations and IS teams had to fight over flexibility vs. low costs. Flexible MES/MOM capabilities with standardized integration finally deliver the ability to ensure that every plant gets what it needs while the enterprise also consistently gains smooth information flows. Ensuring the processes are configured at the detailed plant level and capable of pulling from all other enterprise information systems can truly enable improvements.

In an environment where each group gets what they need, motivation can be higher, fostering collaboration and more rapid progress. Many of the business drivers for investing in MES/MOM depend on complex information flows, so achieving project goals and payback certainly depend on meaningful P2E integration.