Manufacturing Execution Systems and Computer-Enabled Decisions at the Manufacturing System Level

Chris Will, Apriso and FlexNet

Challenging economic trends, rising value chain complexities and intensified global competition have been driving the manufacturing industry to upgrade their legacy manufacturing execution systems for years. Complicating matters are advances in cloud computing, big data, social collaboration technologies and mobility that are driving the modern world towards the digitally-connected enterprise and value chain – one that must ultimately satisfy the demands of a better-educated and socially-aware consumer. These market dynamics and technology advances pose a threat to all while offering opportunities to those who successfully leverage and incorporate them into their mainstream. For manufacturers, the challenges are driving a fundamental reassessment of their current and future factories.

This paper introduces key concepts behind Apriso's FlexNet – a manufacturing execution system built natively on a process-centric software architecture that is optimally positioned to meet these challenges. We will highlight how the platform enables business intelligence by incorporating assisted and automatic decision-making directly into the manufacturing processes. We'll wrap up by exploring some of the opportunities for embedding the emerging technologies mentioned within the approach.

Model-driven Development – The General Case

Throughout the existence of Information Technology (IT) groups within business, the use of models played a key role in allowing technical and nontechnical professionals to work together to debate and define the business processes and requirements of a system. Such models would subsequently drive IT groups to create new applications, refactor existing ones, or help drive vendor selection of an off-the-shelf application and potential customization efforts. Modeling languages and tools proliferated throughout the 1990s with various methodologies springing into popularity only to be replaced by others. Today, the most notable and surviving one is the Unified Modeling Language (UML). After the turn of the century, in part due to UML's complexities but moreover due to the transition to agile, lightweight development methods such as eXtreme Programming (XP), the market for such these tools saw a steady decline.

Yet with the advent of XML and Web services and the shift towards componentizing application functionality into SOA services with seemingly endless possibilities of consuming them into solutions, the degree of complexity of systems grew. This in turn drove a regained popularity in model-driven approaches over the past decade. With advances in graphical software modeling tools, models became the de facto standard between IT and their users to develop and maintain applications and became the primary vehicles for managing systems throughout their life cycles.

From Modeling Processes Executing them – Introducing BPM

Around the time when model-driven development tools based on the UML reached their peak (about the 2002 timeframe), a competing camp emerged which sought to transform models directly into a machine-readable form that could be executed at run-time. This camp sought to eliminate programmers from touching the underlying code once a process was authored, which promised to greatly reduce the need for specialized programming skills to manipulate a solution. The premise of directly executing processes at run-time became central to their vision and a software segment known as Business Process Management (BPM). This would open the door to nonprogrammers such as business analysts, industrial engineers, and even business users, to participate in the stages of system development from design, through initial implementation and throughout its life cycle. Of course the rest is mostly history. Virtually all of the largest platform houses and dozens of start-up firms jumped into the software segment soon to be called as Business Process Management Systems (BPMS).

As BPM vendors sought to model primarily processes versus entire system architectures, specialized mark-up languages based on XML began to take form. To represent and make models transportable across tools, BPM established the Business Process Model and Notation or BPMN. To represent an executable process and make it transportable, the XPDL standard would soon become the de facto standard. BPMN is maintained by the Object Management Group (OMG) [1] whereas the latter is managed by the Workflow Management Coalition [2].

As the BPM market grew, a few vendors chose to offer a core set of technical and functional components built natively on their platform and aligned to a specific business context, targeting particular roles, processes, and associated workflows. Apriso's FlexNet product is such an implementation of BPM. It targets manufacturing operations and brings together engineers from material control, quality, maintenance, and production with IT to configure solutions.

How BPM Helps Accelerate Manufacturing Excellence Programs?

Before we answer this question, a cursory glance at the evolution of organizational development methodologies, and the role IT has played, seems appropriate. Those familiar with manufacturing excellence methodologies such as Lean and Six Sigma – still in wide-spread use today – may recall the intentional absence of any dependency on IT systems like ERP. Others may remember the hugely popular albeit short-lived wave from the early 1990's known as Business Process Reengineering (BPR). While IT played an important role in BPR, it was short lived. In many respects, BPR was largely a shock-wave approach to push Western companies to quickly respond to threats from overseas who exhibited superior performance in a number of key manufacturing performance metrics, and were eroding the U.S. manufacturing base. Those who "survived" the BPR wave by revolutionizing their manufacturing methods, soon had to focus on managing and evolving them. By the turn of the millennium, BPR gave way to continuous improvement methodologies and Business Process Management was born [3].

BPM readily adopted the main tenets from BPR which were to use models of current business processes as a starting point for business analysis, redesign and continuous improvement. With a solid foundation as an organizational development methodology predicated on evolution, not revolution, BPM advocates knew they had to rely on the current IT infrastructures for years to come. IT budgets were severely constrained after the turn of the century and many had yet to show an ROI on their huge ERP investments. So the search began for technologies that would not only integrate with existing systems, but could shape and mold functionality in a manner that aligned with the as-is environment, could be deployed globally, and serve as the means to monitor results and target improvements (Figure 1). Additionally, the birth of BPM aligned well with emerging technologies such as Web services and integration tools that could readily wrap functionality housed within ERP and other traditional applications, and describe data and interfaces in a neutral manner using XML technologies.

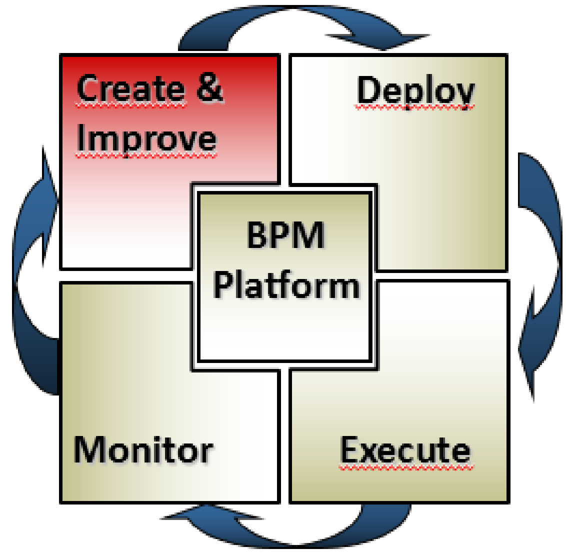

Figure 1 - Continuous Process Improvement on a BPM Platform

In answering the question then of how BPM technologies are ideally suited to accelerate process improvement, standardization and excellence programs, it becomes apparent that their ability to translate the outcome of process modeling efforts into an executable form that limits or eliminates the need to code or customize a core application, is key. In this manner, process knowledge that is captured in the model is kept current relative to the system's implementation. In almost all other approaches, models are retired in stacks of paper or on bookshelves after an initial implementation and became aged artifacts for the firm's historians.

Recognizing that a generic BPM technology is not an application or a solution within a particular business context, the opportunity exists to further accelerate manufacturing excellence programs by pre-configuring and pre-packaging many of the core elements needed for a particular industry. Such packages are built natively on the BPM and contain a unified model of the business entities involved, a core set of fine-grained business services to manipulate the business entities, and a collection of one or more process fragments applicable to the various business areas in that industry including production, material handling, machine maintenance, and human capital management. Starting with a library of pre-configured, process-centric assets eliminates the need to start with an empty page and provides a solid starting point from which the organization can accelerate their manufacturing excellence programs.

Some have referred to the approach of combining BPM technologies with manufacturing excellence programs as outlined in this paper, "Production Process Management" [4]. This is in stark contrast to traditional approaches which are data-driven and application-centric.

Making Processes Intelligent

Processes configured to run under a BPM can exhibit operational intelligence in one of two manners: By guiding users through the complexities of their process, or by autonomously taking some action – presumably an optimal one. Both techniques are based on the system's "knowledge" of the particular problem domain to which it is applied. Such knowledge must necessarily be configured into a process. Although the same approach is used in traditional applications, what differentiates a BPM application is that such intelligence is not coded into the solution.

In a BPM approach, intelligent behavior may be added into a single process controlling a work center or automated manufacturing cell, or an end-to-end chain of processes spanning the entire factory, enterprise or value chain. An example of the former might be to highlight the suggested sequence in which to process work orders so as to optimize a set of competing objectives like minimizing material consumption, maximizing machine utilization, or focusing on the most important customer. An example that spans the entire factory floor is to optimize the supply of component materials to production in a just-in-time manner that honors the production schedule while utilizing floor space in an efficient manner.

The extent to which intelligence can be enabled is limited only by what the manufacturing excellence team authors into its processes and by the kinds of optimization and intelligence tools made available within the BPM platform. Often, the BPM can integrate popular tools on the marketplace including business intelligence (analytics, data mining, etc.), simulation, statistical analysis, artificial intelligence (genetic, inference/rules-based, etc.), and operations research (smart math or constraint-based optimization). Such tools can be tightly integrated into the BPM's underlying design surface and run-time engine, or be loosely-coupled through a service bus or other means. Hybrid approaches are also possible.

For decision support scenarios, the user may receive guidance in the form of in-line feedback. For example, a make-to-order engine manufacturer might configure their assembly operation to conduct a series of back-ground checks of an engine's digital configuration to alert an operator about any authorized bill of material deviations (material substitutions or engine configuration options) or other checks that need to be performed. Or the system might retrieve the specific fail-safe data for an engine configuration to provide additional context to both the automation layer and the operator. Fail-safe data might range from specifying the items and ordering of component materials to be consumed, to the tool calibrations and settings for each step of the assembly operation. The standard work instructions might be augmented to display configuration-specific deviations through multi-media visual aids thereby minimizing the need for the operator intervention on the computer terminal.

Decision support may also manifest in the form of supervisorial dashboards that provide data on the throughput and timeliness of a process, end-to-end performance across the entire factory, or give visual cues as to process abnormalities. Beyond dashboards, the system may alert production staff through email, texting and other notification channels. Automated system actions can also be implemented entirely by invoking secondary business processes, services, or applications, or triggering action within a machine or in the automation layer.

The ability to handle exceptions and incorporate intelligent decision-making natively into the manufacturing processes under control of the BPM, is essential. This provides visibility into recurring process exceptions and becomes the core driver for prioritizing and engaging continuous improvement efforts. Further to that, the ability to provide insight into executing processes opens up the door to in-flight adjustments of process parameters to drive optimal outcomes. Adjustments range from changing product data such as to authorize substitute materials when a shortage occurs, to changing the process to eliminate tasks, adding extra approval steps, redirecting a work item to another work center, or applying alternative business rules. The time scale for such exception handling may involve long-running transactions that last hours, days or even months.

Opportunities for BPM Technology

Connecting the Virtual and the Real – Simulation to Play a Key Role

As market dynamics dictate ever shorter product life cycles, increasingly complex supply chains, and ever increasing costs to bring products to market, one opportunity to explore is when and how to replace physical prototyping of new product introductions and manufacturing processes, with simulation. While the cost to physically prototype and test new products and processes increases, at a minimum at the rate of inflation, the cost and capabilities of the virtual will continue to decrease.

For the use of BPM technologies in manufacturing, a natural place to begin is by looking at the simulation capabilities found in Product Life Cycle Management (PLM) systems. Although there are many applications of simulation by PLM, from design through production to sustenance, those applicable to plant operations include the ability to simulate a sequence of actions and alternatives within the context of a single work center, simulating human ergonomics tied to the physical actions an operator performs at a work center, and simulating the interaction between processes across the entire factory. Because PLM systems can natively manipulate models of processes, they are ideally positioned to simulate how individual workstations and cells perform activities, from the consumption of component materials, to the productive steps performed by an operator or machine, to the movement of materials out from a cell. Likewise, PLM systems can increasingly simulate human ergonomics to ensure that their movements are safe and efficient, given the work instructions to be followed at an operation. If the representation of process models is standardized or based on industry standards, the sharing of PLM's simulation capabilities can be readily consumed and integrated into BPM technologies.

The opportunity to explore is that of incorporating simulation capabilities within the BPM. The challenge with introducing simulation involves not so much technology but rather that organizations implementing BPM have been busy for quite some time implementing BPM projects and utilizing the more mature analytical frameworks on the marketplace. Yet certainly the introduction of simulation to the approach is a work in progress. In particular, simulation and optimization tools can be used in tandem to optimize machine control systems, factory scheduling, and decision support.

From Analytics to Big Data: Gaining Insights from both Structured and Unstructured Data

If we wanted to analyze the as-built manufacturing history of a product to identify the root causes of a quality issue, or search for clues on how to improve production for a part, or any other pattern of interest, large amounts of data must be stored, somewhere. The leading database vendors on the market today have done a great job introducing relational database and business intelligence technologies that structure data in a suitable format allowing it to be viewed and analyzed. But as we well know, these technologies store data in a pre-defined format. Although such data stores can store large volumes of data for decades, it is still structured data and the repository is usually a relational database or a proprietary technology. In the case of manufacturing operations data, details about the as-built product, process or manufacturing history are often dropped for a number of reasons including storage costs, or perhaps ERP was deemed the “system of record” and its database design could not accommodate such details, or the MES transactional database could not retain data for any length of time due to performance concerns. Ultimately, such data would be archived or purged as would the ability to analyze or gain insight from it later.

With the maturity of today’s Business Intelligence (BI) frameworks, the ability to extract details from the MES’s transactional database, and retain such data for years within a reporting and analytics data store, can be achieved at a reasonable total cost of ownership. Yet even relational databases and BI data stores cannot keep up with yet higher *volumes* of data generated at very high *velocities* by sensors, machines and other devices running within the automation layer of a factory. In other cases, there is highly *varied* data (a.k.a. unstructured data) contained within various textual document types, log files, blog entries and other content stored in collaboration portals or e-mail systems. Enter the world of Big Data.

Until recently, only the likes of Google, Facebook, Yahoo, and Microsoft could afford the systems necessary for storing and performing searches against such data. However, Big Data technologies have become both affordable and usable enough for the average organization and IT skillset. Of course the big software platform vendors are rushing to introduce, or have already introduced, search engine technologies that work against both unstructured and relational data stores. Examples here include Microsoft’s SharePoint FAST and their Semantic Similarity Search, or Apache Lucene, which allow you to store such live, unstructured data right inside the database engine, and query it at will.

Introducing search against unstructured data into a BPM platform, whether fitting the profile of big data or not, is of immediate benefit to its users. It is truly rare to find a process that does not link to at least several unstructured document types. In the aerospace and defense industries, collecting volumes of unstructured data in the form of the as-designed, as-built, as-tested, or as-maintained product, has long been a main-stay. Their customers demanded such artifacts be delivered and were willing to pay large sums to have them. With today’s advances in big data technologies, and the low cost of storage and compute power, keeping such details about products and processes is possible for all industries – and they are beginning to see the value and opportunities to be gained in the ability to analyze and gain insights into data they couldn’t even dream of touching a few years ago.

From Processes to Practices – Encouraging Social Behavior to Drive Innovation and Agility

As many businesses embark on the journey of becoming process-centric, and excel at sharing, implementing and improving processes consistently across their global manufacturing base, the question one can ask is what happens when the business becomes too efficiency-focused? What if the business wants to intentionally deviate from standard processes in attempts to discover more effective ways of manufacturing a new product? To do this, they might want to encourage open debate between engineering and manufacturing, between purchasing and quality and amongst other groups. A key capability of next-generation manufacturing is the ability to respond to changes in demand or changes in consumer and market trends, with speed.

Grieves [5], in his book "Virtually Perfect," includes innovation and the other unstructured "practices" that an organization wants to encourage, a critical part of achieving corporate goals and developing an agile culture. To help organizations engage in unstructured practices, IT groups often introduce social collaboration and content management tools. The opportunity here for BPM is what role to play in supporting such unstructured practices? Would not BPM help accelerate the transition from new engineering or manufacturing innovations to well-documented and cost-effective processes during the ramp-up stage of a new product introduction?

Today, there are significant opportunities for introducing novel approaches in content and human-interaction management within a BPM. Under content management is the ability to retrieve, create, update, modify, and correlate unstructured content around the context of a process; support for video, audio, text, and social streams; and content organization around the processes to which content relates. Under human interaction management, is the ability to manage shared work queues, advanced visualization, individual and group collaboration, support for virtual communities, user experience management that is role-based and in the context of process, presence, and providing guidance, and managed notification services.

Where the Future of BPM May Lead Us

With BPM technologies generating billions of dollars annually in revenue, one can readily conclude they pose a significant and growing threat to the traditional market for software development tools. And although the technology can be considered distinct from developer tools as it targets non-developers, this is a nirvana yet to be achieved. Although most BPMs automatically generate a user interface in some form, to deliver a responsive user interface that satisfies today's demanding user on the wide-range of fixed and mobile devices available, requires developers skilled in Web 3.0 technologies.

Yet certainly the technology has delivered on one of its key promises which is the ability to take an initial and continually changing model of a businesses' processes, and keep that model synchronized with an executable form. When that executable form consumes business logic from a library of pre-configured SOA components and a consistent model of business data, BPM can deliver solutions satisfying a wide range of business contexts such as manufacturing operations. The introduction of business intelligence, big data, social, and other emerging technologies into a BPM will allow this technology to remain a viable foundation for any process-centric business that has embarked on the journey from being single-plant, efficiency-focused, to demand-sensing with the ability to adapt at the speed at which their markets change.

References

1. Silver, B. 2011. BPMN Method and Style, 2nd Edition, with BPMN Implementer's Guide: A Structured Approach for Business Process Modeling and Implementation Using BPMN 2. Cody- Cassidy Press. ISBN 0982368119.
2. Wil M.P. van der Aalst. 2004. Business Process Management Demystified: A Tutorial on Models, Systems and Standards for Workflow Management. Springer Lecture Notes in Computer Science. Vol. 3098.
3. Fingar, P. 2006. Business Process Management: The Third Wave. Meghan Kiffer Press. ISBN 0929652347.
4. McClellan, Michael. 2012. Improving Manufacturing Excellence – Managing Production Processes across the Value Chain. Whitepaper. Collaboration Synergies, Inc.
5. Grieves, M. November 2011. Virtually Perfect: Driving Innovative and Lean Products through Product Lifecycle Management. Space Coast Press. ISBN 0982138008.