# Table of Contents

EXECUTIVE SUMMARY ................................................................................... 2  
Problem Statement ........................................................................................ 2  
The Opportunity for an Open Framework ....................................................... 2  
NEW PRODUCT DEVELOPMENT AND INTRODUCTION ................................. 3  
Lean Your NPDI Processes ............................................................................. 5  
ENTERPRISE RECIPE MANAGEMENT OVERVIEW ............................................. 6  
Description of Opportunity ............................................................................ 7  
Business Case for Change ............................................................................... 9  
Typical Business Benefit Calculation ............................................................. 10  
APPROACH TO SOLUTION ............................................................................. 12  
REQUIREMENTS FOR TECHNOLOGY SOLUTIONS ............................................ 16  
USE CASES ................................................................................................... 20  
CONCLUSION ............................................................................................... 25  
BIBLIOGRAPHY ............................................................................................. 26  
AUTHORS .................................................................................................... 27  
REVIEWERS .................................................................................................. 29  

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EXECUTIVE SUMMARY

Problem Statement

The supply chain organizations of today’s manufacturers are under constant pressure to find opportunities to drive efficiency, productivity and speed to market while simultaneously struggling with the proliferation of products spurred by competition, consumer preference, regulatory requirements, specific production facility capabilities, quality and commodity pricing volatility. These needs all encounter a barrier at the human touch points in the process of transforming a formula or bill of material into an executable recipe.

The Opportunity for an Open Framework

Over the past couple of decades, much focus has been placed on creating standards for how products are “defined and documented” in information systems. In addition, the automation and control systems running manufacturing lines/plants have embraced more “open” technologies, easing the ability to integrate them with more enterprise systems. The opportunity now is to leverage the open and integrated technology frameworks and digitally “connect” the worlds of product development with the worlds of manufacturing execution. This “digitization of the supply chain” makes it possible to quickly transfer the information needed to consistently manufacture products across an organization, opening up the real opportunity of a flexible and nimble supply chain that meets customer and consumer demands.

Recently organizations have been driving toward process standardization and optimization across all similar operations. Industry standards such as ISA 88 (recipe standards) and ISA 95 (material, equipment and personnel standards) have been created to enable a common structure/language that can be used to describe an “Enterprise Recipe Management” (ERM) process. The next logical evolution of this standardization process is to create an open framework that can be leveraged across industries. The open framework will enable the development of ERM information systems that digitally connect product development and manufacturing operations while taking into account specific regional and manufacturing operations capabilities.

This connection between Product Development and Manufacturing logically falls within the New Product Development and Introduction (NPDI) process of an organization. A common language connecting the functions within the NPDI processes is needed and, once established, it can be used within and across all ERM systems. These ERM systems will eliminate the need to manually transform product information, starting with the development processes, into manufacturing processes that are consistent across regions or manufacturing facilities. They will enable increased efficiency, productivity and quality of products as well as agility across the enterprise. The following benefits are a few examples that illustrate the magnitude of the opportunity:
- Reduction in search time for data – Estimates of time spent looking for data in the NPDI process range from 20 percent to 50 percent because data is not centralized, is not in a standard format and often is not electronically available to all parties.

- Reduced time to create master recipes – The ERM process defines an “assemble-from-best-practices” method which can reduce the time to develop master recipes by 50 percent to 80 percent.

- Shorten manufacturing planning and site sourcing processes – Planning processes typically require site level knowledge of what materials can be used and what equipment constraints can be met. ERM combines site knowledge (equipment definitions and capabilities) with general recipe information to assist in planning and sourcing decisions.

There are many challenges that stand in the way of achieving this digital supply chain. For multi-site manufacturers, many manufacturing lines have been created and modified over time, optimizing the individual process at one site or for one process or product. This has led to a proliferation of inconsistent definitions of production lines, with a mix of technologies from many equipment and technology suppliers. Each site has focused on its own productivity agenda, and existing product mixes and capabilities, optimizing the site and often driving competition between sites. This has limited cross-site information sharing and suboptimal performance across a multi-site operation.

This whitepaper describes the opportunity to implement an ERM Open Framework. A follow-on whitepaper will further describe the methodology to create an electronic method to transfer information across supply chain systems.

**NEW PRODUCT DEVELOPMENT AND INTRODUCTION**

New Product Development and Introduction (NPDI), and product change processes may be the most complicated and far reaching processes across a company. NPDI can touch every business function, including R&D, Manufacturing, Quality Assurance, Engineering, Logistics, Sales, Marketing and IT (see Figure 1). The processes involved are cross functional, with detailed and complicated information that must be accurately and timely exchanged among different parts of the company. A further complication is that the different parts of the company can be in different locations; even different continents. Not only do NPDI processes touch every part of a business but they can also involve external partners for intermediate goods or even entirely outsourced products.
Yet the survival of many companies is their ability to generate new products, from variations in packaging and saleable units to entirely new product families. In the modern world the mantra is often, “innovate or die” and “get innovations to customers faster than before.” Companies that used to live with 100 day or two-year NPDI and product change cycles are being forced to reduce these times by more than 80 percent in order to survive and prosper. Companies that can’t improve their NPDI processes have lost customers and profits to more nimble competition.

Assuming an average product lifetime of 10 years, it is not uncommon for a company to turn over 10 percent or more of their product definitions per year. For a large company, this can be thousands of new and changed product definitions that must be managed and exchanged per year. In regulated companies there may be fewer new product definitions, but development cycles may be longer with six or more technology transfers and exchanges of information as production is scaled up from lab scale to full commercial production.

It is vital to the long-term success of a manufacturing company to have an effective and efficient NPDI process; yet most process manufacturing companies rely on document and people-centric information and manual processes. In a typical process manufacturing company, such as chemical, food and beverage, pharmaceutical and consumer packaged goods (CPG) companies, the information associated with new and existing products is scattered throughout the company in information silos. Formats for the information include: spreadsheets, legacy systems, point solutions, word documents, automation control systems and the know-how kept in the minds of the employees. There is often no single central source of truth about a product. Managing the NPDI processes then becomes a manual operation, with all the delays and errors associated with manual processes.
Lean Your NPD Processes

Process manufacturing companies have spent hundreds of thousands of man hours on Lean projects and Six-Sigma in order to improve their manufacturing processes, but generally have not used the same Lean strategy on their NPD processes. Yet, these processes, being primarily manual, are rich fodder for improvement projects because there are significant hidden costs and lost time associated with moving concepts to commercialization. The process is often not fully understood, nor fully documented, and there may be no understanding that “it could be better.” One key indicator of a sub-optimized NPD process is when an organization is always trying to rush through the NPD process, maybe even identifying expeditors, whose job it is to push through changes faster than the normal cycle. In Lean studies, if expeditors are used to bypass normal processes, this is a strong indicator that the normal processes are broken. Often the true path of information and workflows is more like in Figure 2, which shows the inherent inefficiencies with multiple paths and loops through organizations as information is discovered, lost, rediscovered and lost again as an idea makes its way to commercial production.

![Figure 2: Typical information flow in an NPD process](image)

Some of the primary problems are determining:

- Who is the process owner of the NPD process?
- Who is the gatekeeper of the process?
- Who supplies data to the product definition?
- Who consumes data about the product?
While an Enterprise Resource Planning (ERP) system may be a router of the data using workflows and sign offs, it is not necessarily the owner of the data or the system used to create the data. The ERP system may also rely on information stored in other systems such as site-specific equipment processing capabilities. An additional complication is that many of the people involved in the NPDI process are not normally ERP users, with access or training in ERP financial or logistics systems. People involved in the NPDI process are typically chemists, physicists, biologists, mechanical engineers, electrical engineers, control engineers, industrial engineers, quality assurance specialists, validation specialists, sales persons, marketing specialists and operations engineers.

**ENTERPRISE RECIPE MANAGEMENT OVERVIEW**

NPDI defines the overarching process, and Enterprise Recipe Management (ERM) is the concept that supports NPDI processes in the process manufacturing industries. ERM defines a standard method for the process industries to manage product definitions across their internal production chain and their extended supply chain. Companies following this approach typically have significantly reduced time and cost of technology transfers and validation. ERM is based on the ISA 88 and IEC 61512 standards, which are widely used standards in the process industry, and define the structure and format for sharing the information required to manufacture products with the same quality and same standards at all locations around the world.

Enterprise Recipe Management is a concept that uses standardized formats for exchanging information about product definitions, processing capabilities and best manufacturing processes. ERM is typically implemented using workflows and associated data structures. The workflows manage product and process information flows within the new product development and implementation work process. The data structures define a standard for product and process information. The goal of ERM is to provide consistent, readily accessible and reliable product and process knowledge that is communicated across functions and geographies in a structured methodology. By design, Enterprise Recipe Management is also a strategic business component of product and process based corporate intellectual capital. Although not primarily focused on the front end of the discovery pipeline, ERM enables continual feedback on and version control of process and product knowledge throughout the development process.

In summary, Enterprise Recipe Management is focused on coordinated management of product and process knowledge through:

- Improving speed and efficiency of product and process knowledge communication between functions involved in NPDI, especially in the areas of technology transfers from labs to pilot production, pilot production to full scale production, and internal to external manufacturing
- Creating organizational accuracy and reliability through consistent product information flow and standardized processes among stakeholders
- Reducing rework, communication delays and duplication of effort among participating functions, creating a standardized process for communication of production information across multiple global facilities

**Description of Opportunity**

Beginning from the point at which R&D is ready for implementation of a new or modified product, a large amount of data and information creation and verification is required such as material specifications, quality measures, regulatory compliance approvals and notifications. In the ERM concept, the information is maintained in a standard format and grows over time as the product definition grows with the information available to all parts of the organization involved in the NPDI processes.

Bench scale description of the product formula and procedure are scaled-up using subject matter experts to create a general recipe that defines the basic chemistry, physics or biology needed to create the product. Plant knowledgeable personnel then develop site-specific recipes that take into account local processing capabilities/restrictions, regulations and material availabilities. Master recipes are created for target specific site equipment and production facility layouts. Multiple master recipes may be created from a single site recipe based on the equipment layout for the site.

Finally control recipes are created from the master recipes and configured with the specific limits of the ERP production order and associated Environmental, Health and Safety (EH&S) constraints.

During the overall NPDI work process, multiple functions are involved in the creation, modification, verification and authorization of information contained within the recipe. A variety of skilled people must be ready to quickly generate, receive, translate and use this product and process information to ultimately implement a new product for sale in the specified geography, within a limited time window and within the correct production environment. At each stage of the recipe transformation, checks are required by knowledgeable personnel to ensure that the end manufacturing facility has the capabilities to execute the recipe. Often these steps can occur late in the process. ERM is a method to allow the information to grow and be shared during the NPDI process with the people and the systems that use it. It is based on the ISA 88 and IEC 61512 standard representations of information and the MESA BatchML and B2MML formats for data exchange.
Figure 3: ERM allows for product information to grow and be shared across the organization

Today, the process of delivering a viable and verified master recipe derived from a corporate approved general recipe is obstructed due to lack of information clarity, completeness and timeliness. This important clarity is lost in large part because alignment of material requirements with the network of available equipment capabilities is not achieved without significant, time consuming manual verification. An ERM solution provides a common repository of process and product knowledge to facilitate automated transformation of recipes from ERP to the shop floor, therefore expediting the NPD process. ERM also includes definitions of site-specific best manufacturing practices that are used in the assembly of master recipes, changing the process from a “recipe authoring” process to an “assemble recipe using best practices” process.
Business Case for Change

In addition to the benefits highlighted in the Executive Summary, the business case for ERM can be made using some of the following potential benefits:

- **Reductions in number of design changes** – Design changes often happen because of information that is lost, not documented or not part of technology transfer documents. Design changes always result in slower development, especially if they are needed late in the NPD process.

- **Better understanding of requirements** – Missing or misunderstood requirements, usually in the areas of product quality attributes, often require multiple cycles through the NPD process. It is not uncommon in NPD processes to hear the phrase, “If we had only known that, we would have done this differently.”

- **More optimized material flow** – Help on sourcing decisions for products can also improve site-to-site material flows.

- **Reduction in time-to-market** – Fewer cycles through the NPD process and less time spent in each individual technology transfer can reduce time to first production by weeks or months.

- **Reduction in the number of test batches** – During the NPD process there are typically at least one and often three test batches run for each new or updated product. With ERM these can be reduced, often to one test batch or even none if the site’s best practices are used to assemble a master recipe. This results in savings of time, materials and often disposal costs for the test batches.

- **Improved labor utilization** – Resources can reduce or eliminate time spent searching for relevant data that may be located in manuals, another person’s knowledge, repeating recipes or steps already completed. Resources can now focus on value-added tasks of NPD with ERM process.

- **Streamlined and enforced NPD processes** – Ensures input from stakeholders is received in a timely manner and that all steps are performed. This avoids last minute changes that cause long delays or steps back in the process.

- **Improved validation of processes** – ERM helps ensure that a standard approach is followed and stage gates introduced to confirm validation consultations are being performed, thereby reducing project risk. This also improves regulatory (quality/safety/environmental) compliance.

- **Overall reduction in product cost** – ERM supports operations efficiencies, improved production throughput, faster product qualifications reducing product launch times, inventory and waste.
NOTE:

- Impact of improvements may vary from 15 percent to greater than 100 percent
- Impact can vary across different industries based on the complexity of the business specific NPD work process

Typical Business Benefit Calculation

The spreadsheet in Figure 4 shows a typical summary of a business value calculation. The value can be determined based on the number of new product introductions and product changes per year and estimates of the hours saved and labor rates. The spreadsheet assumes a full implementation of ERM, but can be used to estimate savings from ERM pilot implementations. Additional corporate benefits may also be estimated for bringing the products into the market faster.
### Enterprise Recipe Management Benefit Analysis

<table>
<thead>
<tr>
<th></th>
<th>Annual Benefit</th>
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<tbody>
<tr>
<td><strong>Products</strong></td>
<td>220</td>
</tr>
<tr>
<td><strong>Variants</strong></td>
<td>5</td>
</tr>
<tr>
<td><strong>Changes per year</strong></td>
<td>10%</td>
</tr>
</tbody>
</table>

#### Corporate Recipe Management Savings due to Single Source of Data

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Products</strong></td>
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</tr>
<tr>
<td><strong>Variants</strong></td>
<td>5</td>
</tr>
<tr>
<td><strong>Changes per year</strong></td>
<td>10%</td>
</tr>
<tr>
<td><strong>Sites</strong></td>
<td>10</td>
</tr>
<tr>
<td><strong>Saved Hours per Year</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Dollars per hour</strong></td>
<td>$100</td>
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</tbody>
</table>

Total: $440,000

#### Master Recipe Creation/Conversion Savings

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<tbody>
<tr>
<td><strong>Products</strong></td>
<td>220</td>
</tr>
<tr>
<td><strong>Variants</strong></td>
<td>5</td>
</tr>
<tr>
<td><strong>Changes per Year</strong></td>
<td>10%</td>
</tr>
<tr>
<td><strong>Work Centers (Cells) Doing Production</strong></td>
<td>30</td>
</tr>
<tr>
<td><strong>Hours per New Master Recipes</strong></td>
<td>10</td>
</tr>
<tr>
<td><strong>Dollars per Hour</strong></td>
<td>$100</td>
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</tbody>
</table>

Total: $3,300,000

#### Test Batch Engineering Savings

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<tbody>
<tr>
<td><strong>Products</strong></td>
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<tr>
<td><strong>Variants</strong></td>
<td>5</td>
</tr>
<tr>
<td><strong>Changes per Year</strong></td>
<td>10%</td>
</tr>
<tr>
<td><strong>Work Centers (Cells) Doing Production</strong></td>
<td>30</td>
</tr>
<tr>
<td><strong>Engineer Time Per Batch</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Dollars per Hour</strong></td>
<td>$100</td>
</tr>
</tbody>
</table>

Total: $1,320,000

#### Reduction of Bad Test Batches

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<tbody>
<tr>
<td><strong>Products</strong></td>
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</tr>
<tr>
<td><strong>Variants</strong></td>
<td>5</td>
</tr>
<tr>
<td><strong>Changes per Year</strong></td>
<td>10%</td>
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<tr>
<td><strong>Work Centers (Cells) Doing Production</strong></td>
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<tr>
<td><strong>Extra Test Batches</strong></td>
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<tr>
<td><strong>Lost Cost per Batch</strong></td>
<td>$4,000</td>
</tr>
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Total: $3,300,000

#### Additional Benefits

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Total: $8,360,000

**Figure 4: Typical business value calculation**
APPROACH TO SOLUTION

The keys to obtaining the benefits from a corporate Enterprise Recipe Management (ERM) strategy are careful planning, organizational support, justification and implementation. A first critical success factor is finding a strong executive sponsor who has a far-reaching sphere of influence and can drive change across the broader organization. Along with this executive sponsor, a cross-functional steering team consisting of leaders from R&D, Engineering, Manufacturing, Marketing, Finance and Information Systems helps ensure success and acceptance of the ERM strategy. There are three main phases for implementing ERM:

1. Identifying and justifying the requirement
2. Developing and piloting the standards, the common language and tools
3. Distributing and sustaining the standards, common language and tools

A defensible justification is important for the project with measurable benefits that have clear linkage to corporate goals. Likewise it is important to develop standards, common language and tools which communicate across functional boundaries and work within your company’s IT and control system environments. This is best done using a low-risk pilot project where you can prove out the concepts before major investments are made for full deployment. A focus on change management will help ensure the new standards and common language are sustained while any systems must be distributed and sustained through rollout plans, policies and procedures.

*Figure 5: Six Step approach to implement ERM process*
The first phase is to identify the business benefit and justify the expense of implementing an ERM strategy. A clear linkage to corporate goals helps with the approval process. This is done by identifying the areas of the business which would have a potential business benefit, as shown in activity 1. Note not all areas of the business may see a potential benefit. Those that may see the most benefit are those having significant new product introductions, a continuing number of recipe changes, multiple production facilities, lack of maturity in having an NPD process or regulatory management problems.

Once the business areas with potential benefits are identified it is important to calculate the hard, soft and strategic benefits as shown in activity 2. Hard benefits for ERM are often reduced time for technology transfers, resulting in faster time to first product and less engineering expense. Soft benefits are savings which are real cost savings or avoidance, but which cannot be reliably measured. Soft benefits by an ERM strategy can be improved cross-site consistency, reduced product sourcing costs and better control of product information. Strategic benefits are those that support corporate goals and may include better regulatory compliance and faster new product introductions.

The next steps are to verify the benefits, link the benefits to corporate goals 3 and identify the target organization that will sponsor the effort 4. While an ERM strategy may have real benefits, if not in line with corporate goals, then it will not receive the high level of support needed for long-term success. An ERM strategy will touch multiple parts of the company with benefits that may not be seen by some of the involved groups, requiring executive support to get all parts of the company on board 5. The sponsoring organization should have sufficient benefits to justify the cost, with executive support, and with the resources to take on a pilot project.

An organization may have to cycle through the first phase several times in order to find the business areas with large measureable benefits, the best tie to corporate goals, the sponsoring organization with the available resources to pilot an ERM solution, and the executive who sees the vision and benefits to champion the corporate direction on ERM.

The next major phase is to develop and pilot a solution in order to prove, or disprove, the justification benefits. This involves forming the project team, choosing a pilot site, developing the standards, developing the solution, executing the solution and evaluating the pilot.
The project team should represent the major stakeholders; in particular operations management, process engineers, control engineers, R&D personnel, product quality personnel, planning and IT personnel as shown in activity ①. The project team will need to create the libraries used in general recipes and transformations, including process action, quality attributes, process parameters, process reports and recipe segment libraries. Therefore, process experts and recipe authors should be part of the team. These libraries provide the common language the organization uses to communicate across all stakeholder groups and are the foundation for the technology solutions to be implemented.

The project team may have to perform a detailed feasibility study, identifying the personnel and technology resources required for the pilot ②. Also, an audit of the key execution platforms should be performed because transformation of general recipes into master recipes must take into account the target master recipe execution environment ③. Particular attention should be given to identifying the ability of the target design environments to export recipes in the BatchML format, and the ability of the execution environment to import BatchML recipes.

The next steps should be to develop the project master plan, roadmap and the data plan for definition of the structured data to be used in the pilot project ④, and to develop any additional technology and company standards needed for the pilot ⑤. When developing the plans it is also important to recognize the steps that may need to remain manual during the pilot, but would be potential for changes in the future.

The next step is to develop a pilot plan that provides an adequate test of the solution to ensure technical success ⑥. The pilot plan can include testing in simulation and/or testing on a physical process. Once selected, the design and execution platforms should be selected that work within the environment defined by the pilot plan ⑦. The requirements and design for systems to create and manage general recipes, convert the general recipes to master recipes, and import the master recipes into the target execution system, should be developed ⑧. The success criteria should also have been determined and agreed to by the system owners ⑨.

The final steps in the development phase are to develop and execute a thorough test plan that has been reviewed and approved by the key stakeholders ⑩. The test plan should include the complete development chain, from R&D through to production, for at least one product. You may have to execute the pilot development and transformation on multiple products, or across multiple sites, to ensure it will work in all business...
critical environments. The results of the pilot should be evaluated to determine if the success criteria was met and to determine if the pilot identified any possible improvements. As with the initial phase, you may have to cycle through several times in order to have a workable system that operates within your corporate IT and control system environments.

The final phase is to distribute the solution with an improvement and sustainability plan. Change management plays a critical role in this phase, ensuring the new language, standards and tools are sustained. The solution will involve policies, procedures and tools, and it may also include regulatory and data governance considerations. However, it must be supported by training and roll-out support. Rolling out ERM often requires support from ERM experts to help the site and/or business area start to build general recipes and develop the structure to transform those into master recipes for the site’s target equipment. This is best accomplished by a focused team that can use their experience from the pilot project and from each subsequent roll out to ease the transition from a paper-based ad-hoc system to an ERM system.

A support team or organization should also be formed to support any tools developed or used by the sites. These tools are often specially focused on management of the recipes and libraries, and may require specialized knowledge not normally part of an IT organization. It is important to have a good set of training and support material available when starting a roll out. Here again, change management practices and techniques in line with any corporate-wide initiative will go a long way in supporting the deployment phase. Wikis, podcasts and blogs can be used to internally market the ERM system and to provide training and support help.
REQUIREMENTS FOR TECHNOLOGY SOLUTIONS

A complete Enterprise Recipe Management program begins with a PLM (Product Lifecycle Management) System of Record and covers the corporate computing environment from the business layer to the automation layer. Although ERM covers a wide vertical swath, enterprises may benefit from a partial implementation that reduces cost and complexity while delivering targeted savings and value. An enterprise with few sites may see the most benefit from automated site to master recipe transformations, whereas, a large multi-national enterprise with multiple sites may see the most benefit from a complete ERM implementation.

Figure 6: Logical flow of ERM transformations from enterprise to physical process

Whether manual or automated, transforming corporate product definitions into executable specific master recipes, as depicted in Figure 6 above, requires work flows, data and well-defined algorithms to complete the data transformations. A reusable library of corporate definitions and site best practice components facilitates productivity and consistency across the enterprise. A technology solution to support ERM consists of a workflow engine to apply rules at various stages of the vertical integration with connected data sources.

Enterprise Recipe Management implementations share common manual and automated workflows. The example in Figure 7 illustrates the complexity that many companies face due to multiple computing platforms and physical locations. The ability to seamlessly
communicate data across multiple platforms via standard data formats is needed to allow for interoperability across the enterprise. The MESA B2MML and BatchML standards are the preferred interoperability solutions for the exchange of data. These standards, based on the industry accepted ISA 95 and ISA 88 standards, provide vendor independent representations in an XML format. Use of a standard representation allows systems with different workflow engines and data structures to exchange information and coordinate the overall ERM process.

**Figure 7: High level systems architecture and logical data flow for ERM**

Formula data is originated and stored at a PLM layer, which often provides a system of record for product information for the enterprise. These records reside in a single repository for the official corporate formulation data, are used as the single reference for the product definition and often serve as the basis for regulatory compliance. Because of the diverse structure of data needed, PLMs based on non-structured or XML databases, or document management systems, are a preferred approach.

Authoring tools are used to create records; the source of information for these records range from paper-based physical records, electronic textual documents to electronic structured databases. While physical device assembly systems use CAD drawings and assembly instructions, chemical and biological manufacturing use recipes, which often require special purpose recipe authoring tools. Authoring tools that maintain databases instead of text files are preferred to support automated recipe delivery processes.
A structured transformation methodology is needed to deliver consistent product quality across the enterprise. This methodology may be manual or automated, or a combination of the two. Automatic recipe transformations require structured source data and a transformation methodology. In addition, when an open source methodology of communicating between computing platforms is needed, MESA’s B2MML is the preferred standard. MESA also provides an open source automated transformation methodology based on the ISA 88 standards to allow freedom of practice in this space in the second whitepaper in this series.

Structured workflows are needed to ensure recipes are delivered consistently across the enterprise. These workflows can be manual, automatic or a combination of the two. Work flow engines should be used to automate business work flows and recipe development procedures. These configurable work flow engines provide a systematic approach to recipe transformation, which in turn ensures a common methodology and delivery across the enterprise. In addition, workflow engines should be used to automate the recipe transformation process when used in combination with recipe transformation rules and equations.

Modern workflow engines automate repetitive non-value added work and allow for defining standard rules or algorithms while reducing human touch points and the probability of human error. The overall infrastructure of PLM, authoring tools and transformation tools should include workflow engines. The workflows should be configurable to match business processes and approval/sign off rules.

Standard interfaces are needed to seamlessly connect data between disparate systems that consume, process and provide information. The ISA 95 Part 6 Standard for Messaging Service Models and the ISA 95 Part 5 Transaction definitions provide a backbone for standard interfaces and should be a preferred integration model. The computing infrastructure needed to automate the recipe transformation and delivery process should follow current industry standard best practices with an outlook to next generation portability. The systems must also operate within the corporate database, network and security infrastructures.

A Service-oriented Architecture (SOA) delivers seamless connectivity across disparate computing programs and forms the backbone of an ERM System. The SOA facilitates the development of a single data model that is accessible to multiple end users without the overhead of managing multiple copies of the same data. Having this single data model has the added benefit of allowing for the segregation of data so that it is developed and used only as needed. This feature contributes to create a more reliable and secure data structure.

Structured databases ensure that data is stored, read and interpreted consistently across the enterprise. Structuring data across an enterprise constitutes a significant investment and requires coordinated effort across multiple organizations. Structuring data may be the first step in the journey to an automated Enterprise Recipe Delivery system. The structuring usually involves a definition of standards for material identification, equipment identification and quality measurements.
The intellectual property of the enterprise is contained in the recipe and cannot be compromised either by unauthorized access, loss of information or unauthorized edits. Any Enterprise Recipe Management solution will require multiple methods of ensuring security. Role-based access prevents unauthorized access to data that is not needed by an individual or organization to complete their work. The ability to define roles delivers data security by segregating data. Prior to design, an audit of the organization's business work flows and role assignments will help when configuring the system to optimize segregation benefits. Another method of providing security is the isolation of data to a secure computing environment that is controlled at the enterprise level. This level of segregation may be needed for product definitions and recipes that are designated as company secrets and/or intellectual property (IP).

Developing a recipe transformation capability can be a manual or automatic process. In either case, knowledge of the process and equipment transformations must be documented. Transformation rules and rules engines are needed to structure and institutionalize process knowledge so it can be used with a workflow engine to automate the recipe transformation process. In addition, these rules should be stored in a library, so there are standard methodologies and productivity tools available across the enterprise. Often equations are also needed to execute conditional transformations and recipe adjustments, such as non-linear scaling rules or scale specific chemical or biological reactions. An equation editor, integrated with a transformation engine, develops, tests and implements equations. Once these equations are developed they should also be placed in a library for reapplication/reuse.

Libraries provide the ability to store and disseminate data for reference and reuse. Common libraries for ERM are:

1. Material Data
2. Equipment Data
3. Equipment Interconnections and Process Routing Data
4. Quality Data
5. Health and Safety Requirements to be Met
6. Recipe Rules (following the ISA 88 standards)
7. Recipe Equations (as an extension to the ISA 88 standards)
8. Recipe Procedures (following the ISA 88 standards)
9. Personnel (access approval, training, etc.)
USE CASES

There are a number of elements that drive the need for recipe transformation for companies. The requirement for recipe management at various levels (general, site, master) and number of steps that need to be applied as the recipe moves through the levels that a company applies are impacted by the following factors:

- Number of recipes to manage (multiple products or few product lines)
- Number of sites to manage
- Number of suppliers or contract manufacturing
- Variation between sites
- Variations in types of equipment or processes to manufacture
- Variations in level of automation for the equipment
- Variations in current level of technology available and standards followed
- Variations in product options that impact assembly or routing
- Production size at sites
- Frequency of recipe changes
- Frequency of work order changes and need for recipe updates
- Recipe procedure variability
- Raw and intermediate material consistency (always same grade, various grades, alternate substitutions)
- Security measures required to protect IP within recipes and how they vary between sites

The table shown in Figure 8 is a high level example of how these key factors impact certain industries.
Figure 8: High level example of how key factors impact certain industries

The following are process narrative examples outlining the requirements for recipe transformation across a variety of industries and manufacturing operations:

1. Hydrocarbons and Feedstocks

In the world of aromatic hydrocarbons, light hydrocarbons plants are very large in scale (thousands of tons per day) with dedicated processing trains for reaction, recycle and material purification. To optimize the use of capital deployment, some hydrocarbon facilities are jointly owned or provide contract manufacturing services producing products for different legal entities. These plants are capital intensive by design with equipment online asset utilization requirements of greater than 92 percent. Continuously-operating plants of this magnitude typically run manufacturing period orders of minimum 30 days in duration. The period orders are driven by a make-to-stock business plan with very large inventory of raw materials and finished goods.

For governance purposes it is important to manage the product specifications at the recipe level to track quality, cost and regulatory compliance of all materials consumed and produced for sale. Yield on hydrocarbon products is significantly impacted by the variability in grade of feedstock, which is provided to the conversion unit. Based on financial optimization of the raw material supply chain the most efficient units are those which can adapt their operating conditions to produce the desired product with the lowest energy and least by-product generated. Depending on the geographical location of the hydrocarbon facility and its material of construction, the raw material feedstocks may require substitution.
In hydrocarbons the basic product composition of matter is controlled by the general recipe specification administered by the ERP system. With the geographical selection of the hydrocarbon facility and its material of construction, the raw material feedstocks’ general recipe is substituted to create a specific site recipe.

By considering the type of feedstock and catalyst, equipment material configuration and required throughput, the site recipe can be transformed to a master recipe/control recipe. The manufacturing units typically operate a fixed unit procedural recipe. The recipe procedure is hardcoded within the process control system and allows for the recipe settings to be parametrically changeable. These parameters include temperature, pressure and flow rate of materials or energy flowing into and out of each unit operation. Changes to or transformation of the recipe parameters are made to accommodate different period order size, product mix required or grade of feedstock available. These variables get applied as the recipe is moved from the site to the master/control recipe.

Since the production duration is long and there is no variability in operating procedures the control recipe contains only process control set points to regulate unit operating conditions. If a grade or product mix change is requested from ERP a different parameterized recipe array is downloaded, or simply referenced at the control layer to affect a new production order.

2. Commodity Chemicals

Commodity chemicals and plastics are typically first or second functional derivatives of hydrocarbon products that are produced in semi-continuous facilities. Commodity chemicals by definition are make-to-stock products produced in multi-million pound quantities. Product specifications and the associated general recipe are governed at a corporate level to ensure product manufacturing in any location conforms to the same performance specification. Changes to the product mix are based on a fixed series of orders (product wheel) to minimize cross contamination between lots. This can be applied by ERM transformations by inserting cleaning or purge routines between certain product mixes. Site recipes are the same granularity as general recipes and accommodate alternative raw material sources based on location of the manufacturing facility. The combination of general/site recipe is governed at the corporate level to maintain compliance with regional Environmental Health & Safety (EH&S) regulatory constraints.

In semi-continuous plastics and commodity chemicals the master/ control recipe procedure is fixed and the control attributes typically hardcoded within the process control system as a selectable parameter within the control recipe array. Changes to the control recipe parameters can be made to accommodate different period order size, or grade of feedstock available.
3. Formulated Products

Further down the chemicals value chain various commodity chemicals are combined using additional conversion techniques to produce goods for defined customer applications. These applications are tailored to customer-specific functional specifications and are made-to-order. Because these products are highly customized, the product recipes and sources of raw materials can be highly variable. It is essential that at the corporate level the material composition of each product recipe be managed for regulatory governance purposes. Control of the general/site recipes must comply with local regulatory agency restrictions for content and labeling. This level of constraint can inhibit the time-to-market and adversely affect the business financial model. To expedite the time constraint of new product introduction, base bulk materials are maintained at the corporate recipe management level and localization of the product formulation delegated through management of change to the regional manufacturing center via the master recipe.

Local material and equipment capability is managed at the master recipe level of product specification. In many cases there is significant variability in regional equipment capability. This capability can be expressed in terms of mass, heat or momentum transfer functions. When a production order is received at the manufacturing location, a recipe transformation is required to match the order with the equipment capability. In most cases specialty and formulated products are produced via batch sequencing processes. The recipe for the production order must address equipment size, heat transfer, agitation or other physical logistics constraints. Given the equipment limitations there may be several options that require equipment to material optimization evaluations and review of transformation options.

Given predefined equipment capability and an optimization analysis, the master recipe is transformed to a batch specific control recipe, including all necessary formula values and procedures to execute the order. The conversion procedures are typically not fixed, requiring additional procedures to acquire and release shared equipment assets and re-order the sequence of tasks, manual or automatic. In many cases cleaning procedures must be included in the control recipe to minimize batch-to-batch cross contamination of different products.

In the make-to-order cases, the control recipe must accommodate significant changes in formula and procedure, therefore requiring the use of a sophisticated batch coordination engine. This engine not only orders the tasks per the control recipe but also keeps track of batch contextual information associated with the lot of material being produced. From a recipe perspective, the master recipe and transformation utility resides at the MOM/MES level of the information system architecture. The transformed control recipe options are pre-configured and are selectable at the time a production order is received from the ERP system. Speed, agility and accuracy are paramount in delivering recipes in a make-to-order business model supporting specialty and formulated product manufacturing.
4. Discrete and Converted Products - Hybrid

Discrete and converted products are further downstream in the chemicals and plastics value chain. In these cases, specialized materials are typically converted to discrete end user products. Examples in this category could be components used in building and construction, automobiles, consumer goods and municipal or private utilities such as water treatment. The manufacturing processes are typified by a primary and secondary processing step where chemicals, natural products or plastics are combined to form a preassembly, usually in a batch-by-batch manner. The output from the primary process feeds downstream batch or continuous processing to form discrete entities, which are packaged for sale to the consumer.

The bulk materials used in primary production are usually governed by regional regulatory agencies. This way the materials that are converted and consumed in downstream discrete products must be approved at the corporate level through control of the general/site recipe specification. Given regional choice and preference, the general/site recipe will be transformed or modified at the regionally maintained master recipe level. With regulatory compliance being a significant requirement the traceability of origin of recipe components from corporate to regional is paramount.

Depending on the type of equipment being used in the regional manufacturing facility the master recipe is transformed to the control recipe to align with the equipment capability. Product is produced in the primary facility against a production order and batches are isolated, quality controlled and subsequently released to the secondary facility for assembly, packaging and shipment. Secondary production typically consists of discrete fabricating machinery which performs mechanical actions to form, fill and machine a final product assembly. The final assembled product recipe may require further transformation at the control recipe level to set the routing or defined options for the product (e.g. include a filter, machine specific hole size). The assemblies may then be tested, aggregated, packaged and stored by dedicated machinery. Depending on the product being manufactured a machine set-up is performed before running the production order based on the master recipe and order requirements. The machine settings are presented as a control recipe of adjustable machine attributes changed programmatically or physically in the field, depending on the level of automation deployed or requirements in the end product.

Planning and scheduling of each production order are managed as discrete events to match and optimize the utilization of materials, machinery and human operators. Again traceability of materials and product quality attributes are managed from primary through secondary to final warehouse product such that the integrity and accounting of the final product is maintained.
CONCLUSION

New Product Development and Introduction (NPD) is a complicated and far-reaching process within organizations. The Enterprise Recipe Management (ERM) approach of this whitepaper offers an industry standard for organizations to realize a number of key benefits and strategic opportunities. When considering NPD and ERM:

- New Product Introduction is the life blood of expanding an enterprise.
- The closer your business model comes to direct contact with the consumer, the more rigorous and timely information needs flow through your organization to launch new products.
- Decisions to enter a new market need both product definition and asset capability to deliver to the market at an acceptable margin.
- Product Lifecycle Management is a work process which brings together all of the elements of an organization to make decisions on the commercialization of new or modified products using a standardized methodology.
- Material and equipment definition expressed as the enterprise recipe is the complete container of information, the bill of information, required to effectively make new product introduction decisions.
- Based on best practices and implementation standards, ERM is an enabler for companies to define and optimize their NPD workflows.
- In short, ERM facilitates a company’s ability to monetize innovation through increased speed, higher asset utilization, lower cost and more effective business risk management and governance.

A detailed implementation guideline will be published by MESA in the future to assist manufacturers/producers and vendors in the successful installation of ERM tailored to a client’s particular business case.
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