

# Towards Manufacturing Execution Systems for the Food and Beverage Packaging Industry

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**Abstract:** In this paper, we describe the issues faced in bringing advanced supervisory and control concepts in the fragmented food and beverage packaging industry. Although packaging equipment manufacturers must cope with tight cost constraints, heterogenous machines, and customers' requests for specialized features, we take the position that time is ready for bringing more advanced features such as automated production flow and full production supervision even in this domain of consumer oriented and highly personalized products. Manufacturing Execution Systems, which have been introduced with success in other manufacturing areas, can be applied in food and beverage packaging taking advantage from recently proposed standards. This effort requires to supplement the software base of existing machines with an interface layer ensuring interoperability according to the existing standards. By consolidating these standards and adopting good design practices, flexible integration, supervision and control of packaging lines can be obtained.

## 1 INTRODUCTION

In food and beverage (F&B) packaging, most products are more than simple "black boxes", i.e. items that must be picked and placed into a larger box and then wrapped together with thousands of identical items. F&B products are consumer-oriented products, and as such they often possess some special characteristics (e.g., label, expiration date, or preferred side for display) that must be taken into account in their packaging. Increasingly often, multiple product fillers are connected to the same packaging area where the difference in product type must be accounted for, or alternative labels must be applied to the same product for marketing purposes. Thus, for a variety of reasons F&B products must be individually tracked and treated during their packaging, taking into account the differences among otherwise similar products shipped from the same line, and sometimes even in the same box or the same pallet.

Until recently, product variation was not too difficult to handle in the packaging area, mainly because of the small number of customizable variables. In the current scenario, however, the complexity brought by product differentiation and marketing requirements no longer can be coped with by manual intervention. Equipment manufacturers must also face the com-

plexity associated with the strong customizations, invariably required in food production and packaging lines, and the need to cope with special machines from different manufacturers. Packaging equipment manufacturers are indeed very attentive to satisfy these increasing customers' needs. Taking advantage from technological evolution of control devices, they are determined to evolve their systems to achieve those characteristics of flexibility and interoperability required by the market.

In this paper, we describe the issues faced in bringing advanced supervisory and control concepts in the fragmented F&B packaging industry. Although equipment manufacturers must cope with tight cost constraints as well as customers' requests for specialized features, we take the position that time is ready for bringing more advanced features such as automated production flow and full production supervision even in the F&B packaging domain. In other domains, such as mechanical production, semiconductor manufacturing and packaging of pharmaceutical products, much higher levels of automation have been obtained in the last 20 years, and the concept of Manufacturing Execution System (MES) has emerged (MESA, 1997). An MES is an information system that drives the operation of shop-floor control devices, provides complete real-time status and pro-

duction data from the field to the ERP, and executes ERP plans and commands. MESes bring obvious advantages in any domain. In this paper, we discuss the obstacles that have hindered so far widespread introduction of an information system like MES in the F&B domain, and we outline a strategy to overcome these obstacles thanks to technological development and emerging standards.

Following a deeper discussion of the issues and motivations leading towards MES-based automation, the emerging standards that can be leveraged upon are described. Next, we illustrate an architecture coping with the heterogeneity of the underlying equipment and enabling non-disruptive, progressive integration of advanced features into existing automation design paradigms.

## 2 MOTIVATIONS

In the last twenty years, production and packaging industries have changed the design and organization of their factories by introducing more accurate and centralized planning mechanism. Major equipment manufacturers are indeed supplying solutions to support production-related activities such as supervisory control, production reports and traceability of finished goods. In this new context, machines belonging to a production line, in addition to the need to exchange information with other machines in the same line for smooth line operation, must communicate with entities outside the line itself. While the need for a new layer of interaction appears everywhere, in several areas, including F&B packaging, a large gap remains between the factory floor and the production planning level. Currently, the goal is to bridge this gap taking advantage from a more efficient organization of information already available and often not properly utilized.

There are several reasons why the F&B area has been lagging on the issues of integration and supervisory control. Cost is one of these issues: the small margins typical of this sector have been a deterrent for investment in production technology. Moreover, the need to cope with the many variations in production previously discussed require more complex MES configurations as well as development of a large number of custom modules. Finally, the need to integrate specialized, heterogeneous and lagacy equipment further increases the complexity and cost of developing an appropriate production supervisory and control infrastructure.

A typical F&B production plant is made up by the integration of many automatic machines such as

blowers, fillers, cappers, wrappers, palletizers, etc., as well as transport systems that handle product flows from the beginning to the end of the line. Heterogeneity of suppliers allows cost and performance optimization of each machine, but often has disadvantages in terms of overall industrial costs, set up times and interfaces harmonization. The major problems, however, are not due to different programming languages or physical connections in the various machine controllers. Rather, most problems stem from the difficulty of handling conventions and naming not homogeneous among the controllers. Since plant operation involves different actors, it is important that they can speak a common language: end users, equipment manufacturers and systems integrators share the interest in identifying terminology, control structures and common organization methods for software programs, so that working together can be simpler and more efficient.

Over the last decade, these issues have led the stakeholders to establish working groups within international organizations with the aim of reaching a standardization of conventions that can meet current needs. Two emerging standards relevant to F&B packaging are PackML (ISA, 2008), developed by the OMAC Packaging Workgroup, and the Weihenstephan standard (Kather and Voigt, 2010) developed by the Technische Universität MÜNCHEN in conjunction with major German industrial players. Interoperability, indeed, represents a new global challenge in automation software.

### 2.1 PackML Standard

The PackML standard (ISA, 2008) has been proposed by OMAC, the Organization for Machine Automation and Control (<http://www.omac.org>), and has been adopted mainly in North America. PackML considers many aspects of line automation and provides guidelines for writing machine software and for communicating between different devices. Adopting the full PackML proposed model requires a particular software organization for each machine, according to a functional decomposition and a predefined state schema. Tables for receiving remote commands and information exchange according to PackTags conventions must be defined. The PackML standard includes also guidelines for Overall Equipment Efficiency (OEE) computation. From a practical standpoint, software refactoring is a process known to be expensive and often cause of potential malfunctions. For these reason PackML offers also a more conservative approach (PackTags-only approach) for standardization of software already developed. This approach

is implemented by simply inserting the data structure in existing software, thereby obtaining a system that at least complies to the standard for external interfacing purposes. This feature is very important for the F&B domain, where legacy and third party hw/sw components must be invariably accounted for.

The full PackML state model is shown in Figure 1. This model represents all states and transitions defined by the standard. The state model is suitable for representing operations of every type of automated machinery. Thanks to the naming convention set called PackTags, each entity can expose all the information inside a computation node (and receive remote commands) in a structured and standardized form. Adopting common naming conventions is possibly the most important issue in an integration scenario: in this way all entities can exchange information without the need to use a different protocol for each different manufacturer. Exporting information using this set of rules allows every other entity in the plant, including supervisory systems, able to know in a fine grained way the state of each machine and react or interact appropriately.

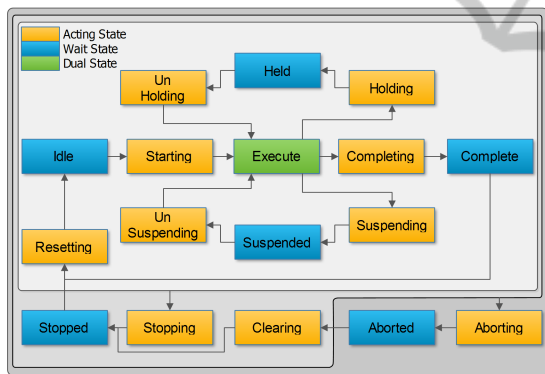


Figure 1: PackMLstate model for automatic operation.

## 2.2 Weihenstephan Standard

The Weihenstephan standard (<http://weihenstephan-standards.com/>), proposed by Technische Universität München and developed in conjunction with major German breweries, is gaining broad acceptance mainly in Europe. The last major version of this standard is called WS2005 (Kather and Voigt, 2010). Its focus is mainly on communication aspects, and for this purpose it defines protocols to be used for each ISO/OSI stack level.

The WS2005 part 2 document includes an exhaustive list of tags for data exchange between machinery and generic Product Data Acquisition (PDA) systems. Compared with PackTags, this set is less structured but more detailed. Tags defined by WS2005 are

specifically designed for packaging and beverage industries, so it would be difficult to apply this tag set outside these sectors. Since the project motivating this paper specifically addresses packaging of food and beverage products, the WS tag set is very interesting, especially in order to integrate the more flexible but somehow generic PackTags set.

The WS2005 standard also provides harmonization directives for interoperation with PackML, so the two standards can share state models and the most important data describing general machine status. This feature leaves designers free to integrate both protocols and allows the design of equipment that can talk with supervisory systems that adopt either standard.

## 3 MES IN PACKAGING INDUSTRY

An MES is an information gateway integrated in the enterprise network ensuring that all data are correctly understood and operations executed in a consistent way (Qiu and Zhou, 2004). MESes operate collecting real-time data from the field and making them available in an aggregate way throughout the whole enterprise, eventually doing some minor computation over the data collected (Figure 2). Their effectiveness does not depend only on the features they offer or the performance they can achieve, but requires a deep involvement of all actors within the enterprise moving towards this new philosophy, that implies elimination of manual intervention on production processes (MESA, 1997).

Automatic data collection performed by MES is characterized by low latency and is transcription error free, so moving information in this way can result in a significant increase in effectiveness of plant operation procedures. MES designs are oriented to short term planning and performance optimization of production lines, and perform coordination operations at a finer granularity compared to ERP systems. Whereas ERP functionalities are not standardized, MESA has identified eleven functional requisite types which can drive MES application in any shop floor (Younus et al., 2010).

Packaging is a challenging domain for supervisory systems. Packaging shop floors usually consist of multiple lines with several specialized or similar machines that can run different jobs with different products and materials. In this scenario, an MES can concur to many aspects of process production, such as order dispatching, plant supervision, events tracking and OEE assessment.

Factors such as higher productivity, cost reduc-

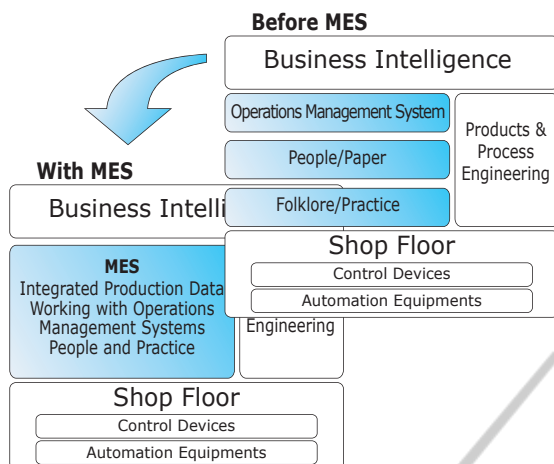


Figure 2: Integrating the shop floor in the business intelligence: Transition from a conventional information system to a Manufacturing Execution System. Adapted from (Qiu and Zhou, 2004).

tions and regulations compliance have always been main motivations to support investments. Achieving each of these goals has resulted in a more efficient resource usage, regardless of the fact that they were energy, materials, human resources or informations. With introduction of MES, efficient resource usage can become a goal, rather than a means (Soplop et al., 2009). Materials management based on production flow instead of intensive storing, real time monitoring of plants, energy-as-a-resource management and dry run prevention, elimination of paper based reporting, ..., are all activities that can be supervised and coordinated by a MES in an optimized way, from order dispatching to finished goods.

#### 4 ARCHITECTURAL OVERVIEW

In this section we provide an overview of a system architecture which achieves in the packaging context the strategic goals associated with integration of a MES. It is very important to remark the scalability of the proposed solution, that allows a sharp separation among business level, factory floor and all other components more closely linked to the core system.

The number of data points managed by a supervisory system may change during its life, due to new investments in equipment, or they may become more important for enterprise planning. Indeed, there is no general purpose hardware configuration that can handle all instances and needs. What is needed is a dynamic entity that evolves based on amount of managed data, required availability and performance constraints. The system should have the necessary com-

puting capacity according to the number of machine controlled, and therefore to the amount of data processed, in order to guarantee minimum latency.

Since the ultimate goal is to supply punctual information about shop floor equipment, allowing immediate intervention when needed, the other issue to be considered is system availability. In this scenario, where a substantial amount of information flows to and from production floor, it becomes important to eliminate, or at least to drastically reduce, system downtimes. As a matter of fact, for information-driven production, system availability close to 100% should be obtained. This goal is pursued with load balancing techniques, increasing the number of critical devices, and, further, implementing store&forward algorithms in software to minimize data losses when only some devices go down.

Figure 3 shows the system logic architecture that can be used in most plants, regardless for their dimensions. Each server role is not linked to a particular physical machine, but it represents a software service that can be run in various configurations like on a single machine or spread across a cluster or in redundant mode with a backup server, depending on plant instance.

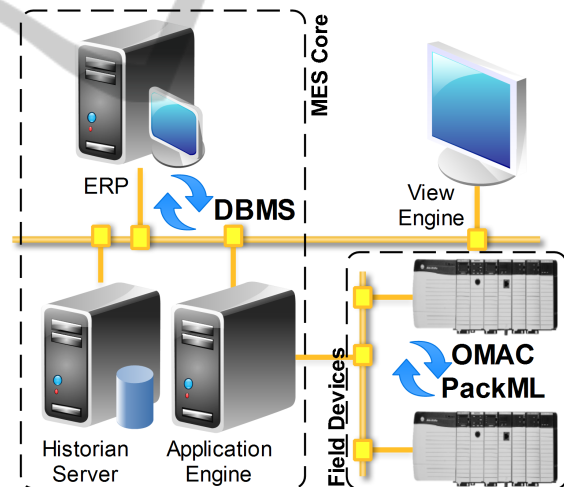


Figure 3: Architecture of a Line Information System for Food and Beverage packaging.

Each node in figure 3 therefore represents a feature of the system:

**View Engine.** It represents the access point to information for standard users. Usually is a workstation where operators can view the system's current status and get notifications if any device is not working properly or requires attention.

**Application Engine.** It is the core engine of the application. Each data change is notified from field drivers and acquired from the application, which

processes and dispatches information to all other nodes over the network.

**Historian Server.** It has the responsibility to store each data received from field devices through the *Application Engine*. All events are recorded in its optimized database in order to build a historical base and retrieve them later for statistical and performance computations.

**ERP.** It represents the contact point with business intelligence systems used at higher levels in the enterprise. The system downloads work orders from the ERP and puts back results and statistics.

A key element to integrate new and legacy equipment in the architecture is the introduction of a state model according to one or both the standards previously discussed in the control software of each machine, so as to enable full interaction with the MES. We have undertaken the effort to implement such compatibility layer for a number of machines involved in several packaging lines, thereby enabling their integration into full Line Information Systems. We claim that this effort is well worth given the potential developments that it makes possible.

A system architecture like the one presented above brings several advantages, due to the deep integration among its components, floor plant and upper business intelligence level. This integration makes possible a bidirectional communication between involved actors as well as the "historicization" of all information related to the plant activities. Thus, the system permits full supervision of process and machines, automating many procedures and doing computations over data. From the enterprise management point of view, this means to have a "plant dashboard" showing an overview of the plant available 24Hx7D and populated with real time data. This dashboard enables production planning and helps in justifying, or more precisely *understanding*, factory performance (e.g. from OEE factors). Likewise, at a lower logical level, line managers can monitor their lines from a single control point as well as be assisted in identifying trouble sources and get reminded of planned maintenance operations.

## 5 CONCLUSIONS

The issues discussed in this paper provide evidence of the revolution that is currently in progress in the F&B packaging domain, regarding line control and machine coordination. Although this revolution started several years ago, only now an overall view of the most innovative market players shows a new model of

plant organization, that is also affecting those who are less caring at these issues. One can't help but notice that the evolution in packaging lines, from electromechanical, to software-based controls, to mechatronic systems, has several similarities with the technology evolution in the ICT domain. In the same way information systems use middleware services for coordinating actions in distributed environments, packaging industries are now ready to move to fully supervised factories that exploit MES as core components to bridge the gap between shop-floor and business levels. In F&B packaging, adopting sound representational and communication standards at the machine level has proven to be a key enabling step for MES-based production and supervision.

## ACKNOWLEDGEMENTS

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