

INFORMATION SYSTEMS SUPPORT FOR MANUFACTURING PROCESSES

The standard S95 perspective

Keywords: Manufacturing Enterprises, Enterprise Resource Planning, Manufacturing Execution Systems, Discrete Processes, Continuous Processes, Batch Processes, Manufacturing Systems Integration.

Abstract: During the last years Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) Systems have been developed in order to support the Manufacturing Enterprise. These two families of systems have been developed independently, so they have grown without a scope or border strictly defined. The feature overlapping between both systems raises relevant issues in the integration with control systems. The main goal of this paper is to analyze how different Manufacturing Processes types (discrete, batch and continuous) are supported by ERP and MES systems, and how the standard developed by ISA: S95 - Enterprise-Control System Integration Standard, defines the scope of each system and provides manufacturing independence. This standard allows the separation of business processes from production processes. To better present the previous ideas, a case study from a paper mill enterprise is presented, where the business processes are identified and a system framework is proposed in accordance with the S95 hierarchy function model.

1 INTRODUCTION

During the last years Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) Systems have been developed in order to support the manufacturing enterprise. These two families of systems have been developed independently, so they have grown without a scope or border strictly defined.

MES systems were initially developed to support the execution of production and have been extended to support quality control, warehouse and order management (Bartley2000). ERP systems' development process was inverse, they began

supporting corporate activities as financial, customer, order processing, sales and distribution (Merrit1999) and have extend their scope to support quality control and production tracking activities. The feature overlapping of production planning and quality control between both systems raises relevant issues in the integration with control systems of the plant-floor (Mark2000). This integration is required for information systems to be able to completely support the value chain integration of manufacturing enterprises.

This context allows three possible scenarios:

- MES products will extend their features to support management processes.
- ERP systems will extend their features to support the execution of production processes.

- MES and ERP systems are integrated in a way that keeps the strong points of each one.

This last integration option assures that the know-how and competencies captured within each system are not lost. This solution will imply a coherent definition of the scope of each system, and a model that defines how information flows between them.

Until mid nineties there was:

- No common model for integration between MES and ERP systems.
- No standard terminology to express system requirements.
- Integration between different vendor products was internally made.
- Maintenance of integration between different systems was difficult and expensive.

In 1995 Instrument Automation and System Association (ISA) formed a committee with several system vendors to develop S95 - Enterprise-Control System Integration Standard (S95200) (Jones2000) (Jovan2002) (Lukzo2003). This standard presents several models to represent how Enterprise Resource Planning Systems and Manufacturing Executing Systems are structured inside Enterprise Architecture. The standard is based on the previous work presented on Reference Model of Computer Integrated Manufacturing (Williams1989) and of the Manufacturing Enterprise Systems Association (MESA) (McClellan1997).

The main goal of this paper is to analyze how different manufacturing processes types (discrete, batch and continuous) are supported by MES and ERP systems, and to evaluate how the standard defines the scope of each system and provides manufacturing independence. To better illustrate these ideas a system framework is proposed in accordance with the S95 hierarchy function model for a paper mill enterprise.

On the next section a brief description of manufacturing process types are presented in order to show the different characteristics between them. Section 3 describes the role of each system and identifies feature overlapping. It presents the main characteristics that all systems should support on the three modes of production. On section 4 the standard S95 is explained in order to show its two main features: where the manufacturing type differentiation is done, and what is the scope of MES and ERP. Section 5 presents a case study of a paper mill, where the S95 hierarchy function model is applied and a system manufacturing enterprise

framework is purposed. Conclusions about the work and the case study, as well as, the future work are presented on section 6.

2 MANUFACTURING PROCESSES

“Business processes are the activities performed within the business during which the state of the business resources changes, describing how work is done” (Erikson2000). It is possible to define manufacturing processes as business processes that transform physical resources. ANSI/ISA classifies manufacturing processes as discrete, continuous and batch. This classification is the one generally used on specification of Industry Software Products. This allows classifying manufacturing processes according to resources type and their relationship with time, as present on Table 1

Manufacturing Process	Time Characteristic	Type of Input Resources	Type of Output Resources
Discrete	Discrete Time	Finite Discrete	Finite Discrete
Process Continuous	Continuous Time	Flow	Flow
Process Batch	Interval of Time	Finite not discrete	Finite not discrete

Table 1 - Manufacturing Modes

Discrete manufacturing processes are of two types:

- Assembling – Several items products are aggregate to compose a finished product. These are typical processes of Automobile Industry
- Disassembling – An item Product is divided on several items products. These are typical processes of A4 sheet paper production.

Manufacturing Batch Processes are based on a recipe that is executed during a finite period of time, consuming finite quantities of products, and produce finite quantities of products called lots. These are typical processes of Fine Chemistry and Pharmaceuticals Industries.

Continuous Manufacturing Processes transform continuous inputs resources into continuous output resources. These are typical processes of Steel and Pulp Industries.

There are industrial cases where the production chain process is based on the aggregation of several types of manufacturing processes. A production process can be composed by a continuous process

followed by a disassembling discrete process for cutting and assembling discrete process for packing, as in the paper industry (Coutois1989) (Schroder1993).

3 MES AND ERP SYSTEMS

Systems to support quality and production planning have to support the different characteristics of each manufacturing type describes on previous section. These differences on Manufacturing Processes have influence on the definition of applications and are resumed on Table 2.

Product identification is base on item number for Discrete Process, lot number for Batch Process and base on time interval or time instant on Continuous. This mode of identification has influence on planning process, quality management and traceability implementations, because all this processes have to manipulate the product entity.

	Discrete	Continuous	Batch
Identification	Item	Time	Lot
Production Planning base entity	Bill of Material	Rate Recipe	Recipe
Quantities	Numbers of items	Recipe Ratio Base	Volume or Weight
Quality	Item base	Time base	Lot base
Trace	Base on product item	Base on product flow	Base on product lot

Table 2 - Systems features for different manufacturing types

In next sub-section we are going to present the specific feature of MES and ERP systems to support Manufacturing Processes.

3.1 MES

“Management Execution Systems provides visibility into production processes” (Ellis2003). MESA International defines the follow list of activities that a full MES implementation support (McClean19997) (NIST1999):

- Resource Allocation And Status – manage machines, tools, material and skills
- Detail Scheduling - Provides sequencing of operations

- Dispatching Production units - Manage the flows of production orders
- Document control - Control documentation that have to be generated during production
- Data collection - Provides a link to obtain the intra-operational production
- Labour Management – Provides the status of the personnel
- Quality Management - Provides real-time analysis of measurements collected from manufacturing
- Process Management - Monitors production provides support to operators
- Maintenance Management - Track and directs the activities to maintain the equipment
- Product Tracking and genealogy – Provides visibility to where work is at all times and dispositions.
- Performance Analyze – Provide up-to-the minute reporting of actual manufacturing operations.

The big issues to solve on MES are:

- Integration with ERP systems.
- Provide the traceability for quality and planning purposes in all types of Manufacturing Process
- Guarantee the coherence on information capture from real-time based systems.

3.2 ERP

ERP - Enterprise Resource Planning, are designed to support the planning activity of all the resources of an enterprise. An ERP system can include software for order entry, accounts receivable and payable, general ledger, purchasing, warehousing, transportation and human resources (Laudon2000). For ERP systems to be able to support manufacturing planning and quality on all manufacturing modes, it is necessary to guarantee the follow issues:

- ERP planning module have to be able to support the three operations types, implementing the differences defined on Table 2
- ERP have to be able to support a production chain with different manufacturing processes types. For this, ERP systems have to know how to convert units’ identification and product characteristics during the process type transformation.
- ERP systems have to be able to receive and send data from control systems in order to do real-time planning and scheduling.

- ERP works in a transactional mode and control systems in asynchrony mode. This difference difficulty the integration between them.

3.3 Overlapping features

On previous sub sections, it is explained which are the main features and strong points of each application type. This study provides the identification of the overlapping features between MES and ERP systems. Table 3 presents this study where business activities are defined according to the Value Chain Model (Porter1995), that identify at the business level which are the specific activities that add value to a product and “where information systems are most likely to have a strategic impact” (Laudon2000).

- Inbound Logistics include activities of planning raw material, receiving and storing raw material, usually these activities are supported by ERP systems.
- Manufacturing aggregates activities of planning, execution and quality control, the manufacturing execution activity is the core capability of MES systems.
- Quality control is activity usually well supported by MES systems. ERP systems’ planning is usually based on Bill Material or Recipe entities that do not cover all Industries Operations requirements (Merrit1999).
- Outbound Logistics as Inbound Logistics are well supported by MES and ERP systems on storage management, planning and execution of delivery activities.
- Sales are composed by the activities of order fulfilment, order planning or invoicing an order which are supported by both MES and ERP. When the customer policy is supply police, or available to promise the order deliver date have to be checked or calculate, and this operation used production-planning operation, that in some type of industries as referenced before is better supported by MES.
- Service Activities aggregates activities of receiving and process a reclaim.
- Support activities as Human Resources, Procurement and Administration are better suited in the scope of ERP systems.

The coexistence of both systems in a coherent and robust way is a challenge. A goal of the ANSI/ISA standard is to define a model to integrate these

different systems solving the overlapping problem, as we going to present on next section.

Processes		ERP	MES
Inbound Logistics	Plan	Well	No
	Receive	Well	No
	Store	Well	No
Manufacturing	Plan	Medium	Well
	Execute	No	Well
	Control Quality	Medium	Well
Outbound Logistics	Plan	Well	No
	Store products	Well	No
	Deliver	Well	No
Sales and Marketing	Promoting	Well	No
	Selling	Well	No
Service	Receive Reclaims	Medium	Medium
	Repair	Medium	No
Human Resources		Well	No
Procurement		Well	No
Administration		Well	No

Fit	Well	Medium	No

Table 3 - General Application Fit Comparison

4 ANSI/ISA S95 STANDARD

“The ANSI/ISA S95 standard – Control Systems Integration provides standard models and terminology for defining the interfaces between an enterprise’s business systems and manufacturing control systems”.(S952000) The S95 standard was developed to provide a common model of integration, a standard terminology to define system requirements and integration between different software vendors(EnteGreate2002). S95 is based on three models: Hierarchy Model, Functional Model and Object Information Model.

4.1 Hierarchy Model

Hierarchy model is composed of two sub-models, Hierarchy Function and Hierarchy Equipment. The

first one is illustrated by figure 1 and specifies 5 levels:

- Level 0, 1 and 2 are the levels of process control where equipment is controlled, in order to execute production processes.
- Level 3 is the MES level and is responsible for the activities of prepare, monitor and complete the production process that is executed on level 0, 1 and 2. These activities were defined on section 3.1.
- Level 4 have ERP systems. The systems from this level are responsible for execute the activities of financial and logistic.

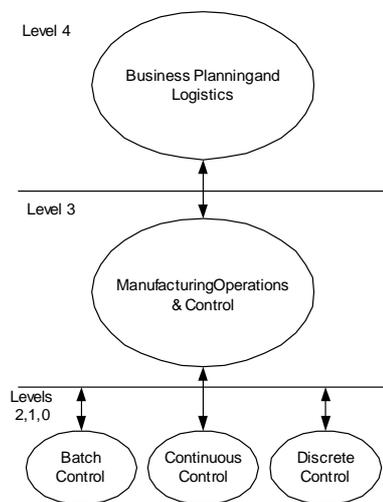


Figure 1 - SP5 Hierarchy Functions Model (S952000)

Equipment Hierarchy Model defines which mill equipment belongs to each level.

4.2 Functional Model

Functional Model presents the functions of a manufacturing enterprise and defines which information cross-level 3 borders. The model defines three types of functions:

- Functions supported just by level 4 -Order Processing, Product Cost, Product Shipping Administration, and Procurement.
- Functions supported just by level 3: production control
- Functions supported just by both levels: Material and energy control, Quality, Product inventory Control, Product Scheduling, and Quality Assurance.

4.3 Object Information Model

The Object Information Models are presented based on UML (Unified Modelling Language) and show how information's objects are structured and the relationship between them. This model classifies information in three categories: Product Definition, Product Capability and Production, as shown on figure 2.

- Product Capability Information defines the resources available to Production (material, personnel and equipment).
- Product Information defines how to make a product and aggregates product production rule, bill of resource.
- Production Information defines actual production and includes:
 - Product History that is the information recorded about production.
 - Inventory Information that is about inventoried material.
 - Information Scheduling that is about scheduled production information.

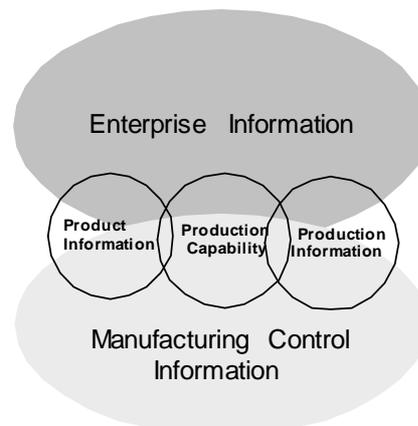


Figure 2 - S95 Information Object Model (S952000)

4.4 Support of different Manufacturing Processes types

On previous section it was explained how differences on manufacturing process have to be mapped into the systems. By the analysis of the standard, in order to understand how models differentiate the three types of manufacturing processes, the follow points were identified:

- **Equipment Hierarchy Model** define different equipments according to manufacturing process type:
 - Batch Process – Process cell and unit are defined according to ISA/ANSI S88 standard.
 - Discrete Process - Production line and work cell are defined
 - Continuous Process - Products units are defined.
- **On Information Model the Product Segment** object that describes how the operations are done.
 - Discrete Processes - define operation as assembly steps
 - Batch Process - define operation as one location operations
 - Continuous Processes – define operation as unit-operations
- **On Information Model the Process Segment** identify the capability can be defined in absolute units or rate units.

independent from manufacturing type. Those differences should be supported on Layer 0, 1 and 2 systems. However, from the perspective presents on section 3 there are several manufacturing issues that not depend only from levels of process control as planning production traceability and quality control.

5 CASE STUDY

On previous sections is presented the scope of MES and ERP systems products and analyzed the support of the different Manufacturing Processes types by each one. It was also present the solution provide by the standard S95 to the integration between this systems. To better illustrate these ideas it was analyzed Paper Mill Enterprise Processes in order to propose a system framework in accordance with the S95 hierarchy function model. Paper Production process was selected because provides a complex scenario where continuous processes, discrete processes, and batch processes are aggregate in their production chain.

In ANSI/ISA perspective, the implementation of S95 standard guaranties that MES and ERP systems are

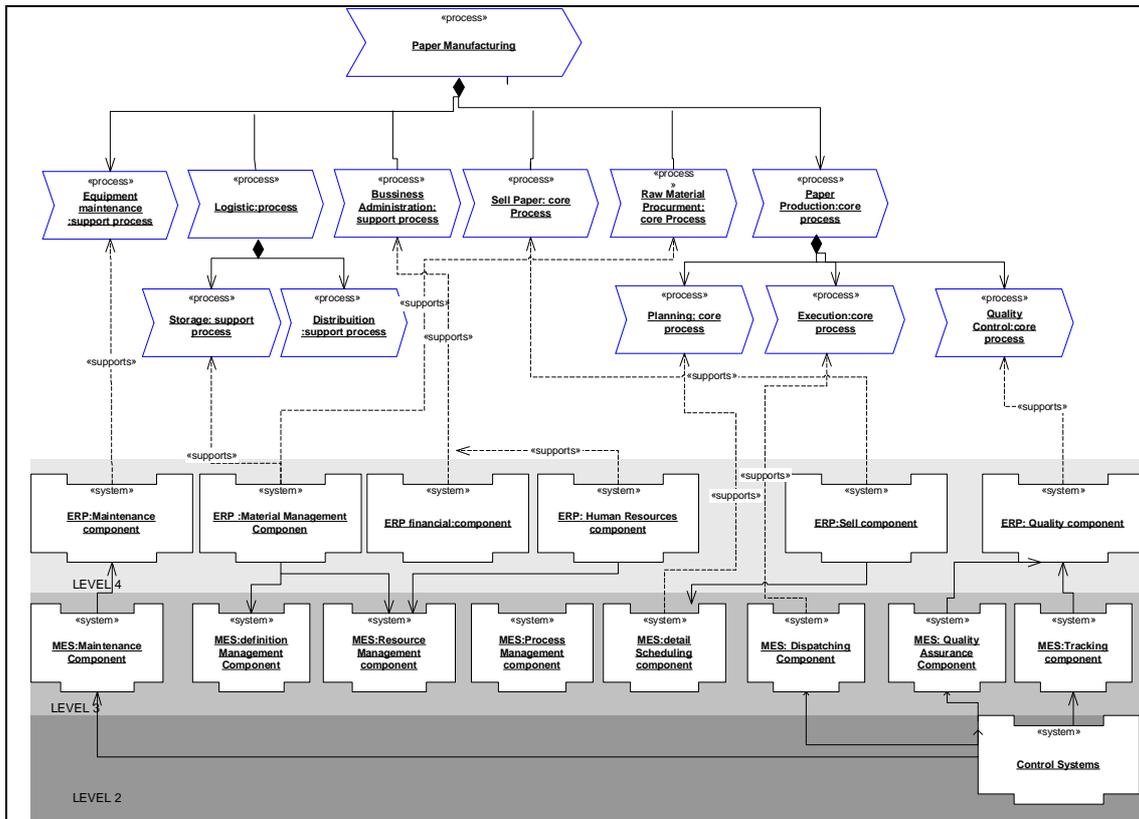


Figure 3 – Paper Production Process-System Diagram

To construct the framework represent on figure 3 diagram (using CEO framework based on UML) (Vasconcelos2001) the follow methodology was applied

1. Business Process modelling of a Paper Mill, using Spewak methodology (Spewak1992).
2. Identify the feature of ERP components, MES, and identify witch general Business Process they support.
3. Follow S95 Hierarchy Functions model the activities of each level are analyzed (section 4.1).
4. From S95 Functional Model Functions the process that should be support by level 3 systems and level 4 systems are identify
5. From point 3 and 4 its infer which MES component and ERP component support each process

A possible way of portioning MES system in components it is considering the eleven activities defined on hierarchy functional model. However in this implementation it is used just 8 components, because Performance Analysis, Data Collection, and, Document Control are support activities. It was assumed that these activities were support by the MES components that need them.

The model presented on the diagram illustrate that:

- Sell Process is supported by ERP level, it can use information from level three to complement order fulfilment.
- Quality Process has a high level management on level 4, but the management and analyses of quality data are on MES systems
- Production Planning, and Execute Production Process are support by MES systems
- Maintenance has a high level management by ERP, and an operational management by MES systems. Data from equipment is manage by MES system,
- Costing Process and Purchasing Orders Process are supported by ERP level.
- Inbound logistic and Outbound logistic are processes also supported by level 3 and level 4 systems

6 CONCLUSION AND FUTURE WORK

“A major business challenge for large enterprises is to achieve the proper level of decentralization that is

to assign responsibility and decision making to the appropriate organization level” (NIST1999). The hierarchy models defined on S95 standard provide a tool to build a manufacturing enterprise system framework where the decentralization concept is applied on Information Systems Architecture.

The standard defines an object information model, however uses a functional approach and not an objected oriented one. This approach has the following disadvantages:

- It provides no clear definition between functions and objects entities relationship.
- It hardens the application of the models when following a business process oriented methodology.

On the presented case study the interconnection between the several components systems is not defined, as it presents research field yet to be explored.

The perspective presented on section 3 defines several manufacturing issues that have to be supported by MES and ERP systems. However from ISA perspective MES and ERP systems are independent from manufacturing process types. According to the standard systems from layer 0, 1 and 2 should support the differences. The research that is being developed, using the paper mill enterprise as field work, will allow to detail the manufacturing processes model in order to apply S95 to a multi manufacturing process type (see figure 4). This will allow to explorer the hypotheses that systems from level 3 and level 4 have also to support the manufacturing process type differences.

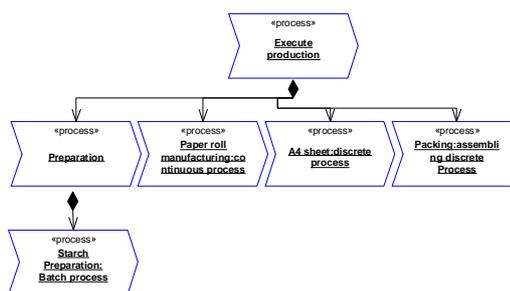


Figure 4 - Process Diagram of Paper Manufacturing

Another issue that is under research is how the information entities could be defined to guarantee the integrity of information along system components of the same level and across component

systems from level 2 to level 3 and from level 3 to level 4.

Reference Model for Computer Integrated Manufacturing (Williams1989), from where hierarchy function model was based, introduced level 5, for multi-plants enterprises, where sales, orders and high level scheduling management are defined as functions of the corporate level. Assigning responsibilities to a level depends also on enterprise business practices, however it is essential to have models that allow for an enterprise system framework where these business practices are mapped.

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