THE ROLE OF CHANGE MANAGEMENT IN A MANUFACTURING EXECUTION SYSTEM

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Abstract:
The difficulty of integrating administration and production is referred to as Manufacturing Operations Management (MOM). A Manufacturing Execution System (MES) is the (combination of) software system(s) operating the MOM layer. Production environments are dynamic, with constantly changing products and manufacturing processes. An issue that haven’t yet received the full attention it deserves, is MES/MOM change management. At initial adoption, a good balance between goodness of fit and flexibility must be strived for to minimize the Total Cost of Ownership (TCO). Three types of MES changes are identified: updates, operational changes and model changes. The MOM framework of the ISA 95 standard is believed to be able to structure the change management efforts. By using ISA 95 based change management the coding and maintenance costs – associated with operational and model changes – can be drastically lowered. Some examples are given to explore the approach.

Keywords:
manufacturing execution system, manufacturing operations management, ISA 95, change management, Lean

1. INTRODUCTION
In a continuous struggle to remain competitive, manufacturing companies try to boost performance, improve quality and cut costs. In order to achieve that, software support is essential [1]. A Production/Process Control System (PCS) ensures efficient daily manufacturing activities, resulting in qualitative finished products. Enterprise Resource Planning (ERP) software maintains important business data and supports the administrative processes. Administration and production were typically treated as two separate islands. The difficulty of integrating those two completely different worlds, has had its share of attention in literature so far [2][3] and is now commonly referred to as Manufacturing Operations Management (MOM). MOM was first introduced within the ISA 95 standard with the following definition [4]: ‘The activities of manufacturing operations management are those activities of a manufacturing facility that coordinate the personnel, equipment, material, and energy in the conversion of raw materials and/or parts into products. Manufacturing operations management includes activities that may be performed by physical equipment, human effort, and information systems. Manufacturing operations management is subdivided into four categories: production operations management, maintenance operations management, quality operations management, and inventory operations management.’ The question mark in figure 1 indicates the position of the MOM layer. Different kinds of software tools can collect and analyze real-time data and turn them into valuable knowledge to further optimize manufacturing operations. Production departments have always favored the development of custom-made software applications, due to a lack of attention paid by information system specialists to the shop floor. However, the difficulty of integrating multiple point systems has brought software providers to package multiple execution management components into single and integrated solutions or so-called Manufacturing Execution Systems (MES) [5]. In this work, the term MES will be used to describe the (combination of) software system(s) operating the MOM layer\textsuperscript{1}. As well

\textsuperscript{1} MOM software or platform [6] also describes that collection of software. In this work, MES is used to clearly differentiate between the framework (MOM) and the application (MES).
production as quality, maintenance and inventory activities can be incorporated and supported by the system. The actual system can be a customized solution, a combination of integrated subsystems, ERP extensions, dedicated (MES) systems, etc.

![Diagram](image.png)

**Figure 1:** Manufacturing Operations Management: the gap between the administration level and the production level

Production environments are dynamic, with constantly changing products and manufacturing processes. Today’s challenging business environment drives the adoption of Continuous Improvement (CI) initiatives; such as Lean and Six Sigma; in pursuit of business and operational excellence. MES contains a treasure of information that can be used to support the decision making process. Automating information flows in the MOM layer, can reveal opportunities to further improve manufacturing operations by CI initiatives. Benefits can reach further than the initial goal of purely automating information flows. The everlasting change lays a dual task on MES: supporting the change process, but also controlling the achieved improvements [7]. By imposing the new way of working, the improvements can be maintained. An issue that haven’t yet received the full attention it deserves, is MES/MOM change management. No research has been found that describes the post-implementation aspects of MES. Although this phase represents a significant part of the Total Cost of Ownership (TCO) of such systems. The usability of the software system highly depends on its ability to reflect the current manufacturing situation. An MES should always present the data wished for by the user, at the right format, at the right time, at the right place. The CI of MES itself is important to keep the system reliable and to standardize the new way of working.

Chapter 2 describes a number of change management aspects considering the MOM evolution. An overview is given of typical manufacturing changes that affect MES and require a change management approach to prevent MES (or the achieved improvement) of becoming obsolete. The MOM framework of the ISA 95 standard is believed to be able to structure these change management efforts. Some examples are given in chapter 3 to explore the approach. The required change management steps for a transition from push to pull are documented. Also some operational changes are described; such as new equipment, new products and KPI reporting. Chapter 4 concludes and mentions further research opportunities.

### 2. MES/MOM CHANGE MANAGEMENT

The digitization of manufacturing operations typically follows a phased, instead of a ‘big bang’ approach. Through low hanging fruits, the important buy-in at each level in the organization can be achieved. The incremental MES adoption can start with functionalities as data collection, order tracking, material tracking
& tracing, KPI reporting, etc. Contingency theory operates from the assumption there is no “one best way” to carry out a task. The success is contingent on internal factors within the organization, and the manner in which it is implemented [8]. Contingent factors are for example: company size, manufacturing sector, manufacturing strategy and standard operating procedures. Due to the uniqueness of each implementation, a thorough analysis is needed. Setting up User Requirement Specification (URS) documents is a crucial first step. By modeling the AS-IS situation, everyone is forced to question the current way of working. Problems get discovered and inefficiencies revealed, resulting in a TO-BE situation. The URS documents define the conditions for initial MES selection. Consultants and practitioners have developed a number of structured approaches for the selection process, e.g. based on the ISA 95 standard [9].

Goodness of fit² and flexibility of software are often conflicting goals. Custom coding can deliver an ideal system at the time but generate excessive costs to maintain, reconfigure or adapt the system in the future. At the other hand, a standard system may require to alter the normal way of working of the company and result in an efficiency decrease or perhaps a loss of competitive advantage. An off-the-shelf solution represents an approach that requires a company to adopt best practices, but not necessarily those best suited to the company, possibly resulting in failure. A good balance must be strived for to minimize the TCO. Figure 2a gives a simplified graphical representation of this optimal fit. The different cost parameters are described in Table 1. The actual cost values (and their ratio) can strongly vary from case to case, but an idea is given of the typical trending. Focusing on this optimal point must compensate for the natural tendencies toward over-complication, over-automation and rigidity, in order to realize the benefits of Lean IT [10]. The possible effect of an efficient change management approach is drawn. The coding and maintenance cost can be reduced, resulting in a lower overall cost for a better fit to requirements at the new optimal fit. After the initial MES adoption, Lean IT must manage change incrementally and continuously to be able to achieve full system potential [10]. That phased implementation plan of the MES adoption is shown in Figure 2b.

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² Measures of goodness of fit typically summarize the discrepancy between the usefulness of the model/system at hand (here: MES) and the actual model/system requirements.
### Cost parameter | Description
---|---
**Coding cost** | The cost for custom coding activities to make the solution fit the requirements. This cost increases linearly with increasing goodness of fit. Configuring a standard solution normally requires less effort than creating an application from scratch, resulting in a smaller slope of the curve. But license costs cause a higher starting point on the Y-axis.

**Efficiency cost** | By automating information flows, efficiency is increased in normal operation. Working without MES results in a penalty cost, that decreases gradually by increasing goodness of fit. This penalty reaches zero when MES exactly fits the requirements.

**Usability cost** | MES needs to be user friendly in its interactions with operators, managers, etc. and needs to be adjusted to the company’s way of working (and not the other way around). Operational changes (new product definitions, new equipment, new reports, etc.) must be supported. A penalty cost is associated with this usability and increases with decreasing goodness of fit. The exponential curve denotes the importance of the social acceptance of the system. The value of a software system highly depends on the way it is used.

**Maintenance cost** | Creating an application that perfectly matches the current situation, greatly increases the possibility of change and the associated costs to maintain, reconfigure or adapt the system in the future. The exponential curve illustrates the increasing effect when approaching exact fit.

**Total cost** | Adding all costs creates an overview of the Total Cost of Ownership (TCO) of MES accounting direct (coding) costs, indirect (maintenance) costs and benefits (efficiency and usability). The presented elements are not very detailed but serve the purpose to explain the change management balance.

Table 1: The meaning of the different cost parameters considering MES change management

Change management is an on-going process whereby the current state is determined to be inadequate. People, organizational structure, technology and processes are important pillars of change and need to interact appropriately to handle its complex nature [10][11]. This work focuses on the role of technology, namely MES, within change management. The MOM framework of the ISA 95 standard [4] is believed to be able to structure these change management efforts [12][13]. This ISA 95 based change management process supports the development of change work flows for on-going operational change and provides a basis for developing a full-scale change management process to facilitate implementing major system and process changes.

Three types of MES changes are identified: updates, operational changes and model changes. Updates are small incremental (automated) software improvements to fix errors and bugs or to boost performance. These deviations to the requirements usually come to surface from the moment the system is actually being used. Operational changes are changes introduced within the boundaries of a company’s existing MOM model (i.e., a new product introduction, installation of a new equipment, a revised product flow, etc.). MES supports these changes by offering the ability to modify its internal structure and information through a predefined change workflow. An efficient and user-friendly human machine interface must enable these changes and guard the integrity of the MES data models and information flows at all time. The support for operational changes is part of the system requirements. The (balance of) costs associated with these changes are incorporated in the coding and usability cost. Changes that alter the company’s MOM model (being the structure of MES), are referred to as model changes. These changes are more radical (and as a consequence more expensive) because they require a change of the system itself. By using ISA 95 based change management the coding and maintenance costs – associated with operational and model changes – can be drastically lowered. In addition, standard ISA 95 object data model changes can be constructed to transform the costly model changes to operational changes. What results in the effect previously shown in figure 2a.
3. ISA 95 BASED LEAN CHANGES

Within the MOM framework of ISA 95, standard model changes can be incorporated. The ISA 95 object models can be used as a uniform manufacturing structure and terminology. Operational changes can be configured quickly while the costs will be restricted to a minimum. Adding new equipment is a relatively small operational change in MES, because it only affects one resource model, namely equipment, within the activity production resource management. However, complexity may increase when an operational change affects multiple object models within multiple activities. And even more, when the change spans over multiple subsystems. Take a new product introduction as an example [12]. This change affects object models within the activities production definition management, production resource management, quality operations management and inventory operations management. But with one click, the required structural extension can be made within the ISA 95 framework, just asking the user to fill in the blanks. A new final product, means the creation of a new product production rule, a manufacturing bill, possibly new product and process segments, new raw materials, etc. Not only can ISA 95 guide the change work flow, it can already perform a great deal of the work, and as a consequence reducing change-over time and possible errors.

Let’s consider KPI reporting as a next example. Standard KPI definitions, like Overall Equipment Effectiveness (OEE), can automatically be configured within the ISA 95 framework. Availability, quality and performance information of equipment (or process segment) objects must be available in the activity production performance analysis. Figure 3a shows part of the production activity model that describes which other activities must contain and deliver the requested information. If, for example, quality data is not available, a change request must be issued to track this information in the future.

Previous work [7][14] discussed the integration of Lean tools, with a focus on Value Stream Mapping (VSM), within the ISA 95 framework. The method uses the available historical information within MES to support or validate the analysis. In the same way, production control can be shifted from push to pull. Figure 3b shows the part of the production activity model that is involved. Based on the given production schedule, the current push system (detailed production scheduling) generates a production schedule with different production requests (products) containing a number of segment requirements (operation). Based on this schedule, production dispatching regulates the flow of production orders. Detailed production scheduling gets disabled within the pull system (e.g. Kanban). Historical information within MES can support the Lean analysis providing takt time, cycle times; leading to the selection of the pacemaker process and the calculation of kanban sizes. Production dispatching is the E-Kanban system, extra process segments are configured as kanban walls. Production tracking must provide the essential real-time information about the flow of kanbans.

![Figure 3: Parts of the ISA 95 production activity model that reflect change management steps for ...](image-url)
4. CONCLUSION AND FURTHER RESEARCH

Production environments are dynamic, with constantly changing products and manufacturing processes. The everlasting change also triggers an evolution of MOM. The task for MES is dual: supporting the change process, but also controlling the achieved improvements. At initial adoption, a good balance between goodness of fit and flexibility must be strived for to minimize the Total Cost of Ownership (TCO). Three types of MES changes are identified: updates, operational changes and model changes. By using ISA 95 based change management the coding and maintenance costs – associated with operational and model changes – can be drastically lowered. A first idea for standard data model changes is explored based on some typical (Lean) change examples. This approach will be tested on existing MES data models to validate the feasibility. MES/MOM change management is seen as a crucial component within the Lean MES framework. A real challenge still remains in trying to really quantify the effect on the TCO of MES.

REFERENCES