THE ROLE OF A MANUFACTURING EXECUTION SYSTEM DURING A LEAN IMPROVEMENT PROJECT

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Abstract:

Observation is a key aspect within a Lean improvement project. The project team starts from scratch and analyses the current situation by walking through the production process. During the last decade, the digitization of manufacturing operations has had its share of attention. Different kinds of software tools collect and analyze real-time data and turn them into valuable knowledge to support and optimize manufacturing operations. These systems are commonly referred to as Manufacturing Execution Systems (MES). The historical data – incorporated in these systems – can be used to support or validate the Lean efforts. As MES enforces the standard way of working on the production floor, it is also crucial to (re)align the system with the Lean improvements. A case study within a food and beverage company illustrates this dual role of an MES during a Lean improvement project.

Keywords:

manufacturing execution system, manufacturing operations management, continuous improvement, ISA 95, Lean

INTRODUCTION

Production environments face constant pressure to produce better and faster in order to remain competitive. It’s a continuous struggle to eliminate unnecessary production costs; improve manufacturing, process and business performance; increase throughput; reduce cycle times; maintain quality; etc. In support of those goals, an adequate level of automation is strived for. A production/process control system 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 and is commonly referred to as Manufacturing Operations Management (MOM) (MESA, 1997; ISA, 2000). The main goal is to achieve a digital information exchange instead of paper or spreadsheet based communication. Nowadays, efficient manufacturing operations without software support has become unthinkable in many cases, due to legal provisions, high product mix, etc. Different kinds of software tools 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) (Saenz et al., 2009).

Company strategies and business requirements need to be continuously adjusted to follow the latest customer requests and industry trends. Production environments are dynamic, with constantly changing products and manufacturing processes. Today's challenging business environment drives the adoption of continuous improvement initiatives; such as Lean and Six Sigma; in pursuit of business and operational excellence. This everlasting change lays a dual task on MES: supporting the change process and controlling the achieved improvements. Cottyn et al. (2011) describe the use of the MOM framework to align an MES with Lean objectives.

In this paper, the objective is to analyze the dual role of an MES within MOM change management. The first section describes the continuous improvement of manufacturing operations. Starting from an initial MES adoption, the digitization of MOM is gradually implemented through subsequent innovation steps. The implementation is contingent on a number of factors, making each case unique. In between innovation steps, the extra visibility – provided by the MOM software support - can lead to additional value creation beyond the initial goal of automating information flows. MES is an enabler of continuous improvement programs. This concept is illustrated by a stepwise MOM evolution of a small furniture manufacturing company. In the second section, a Lean improvement project at a food and beverage company demonstrates the role of an MES at a given moment in time. As it is still work in progress, the focus lays on the methodology. The last section concludes and states future directions to refine this research.

CONTINUOUS IMPROVEMENT OF MANUFACTURING OPERATIONS

Filling the gap in between administration and production is not a trivial task. The emergence of functional (MESA, 1997) and integration (ISA, 2000) standards defined the structure of the MOM framework in Computer Integrated Manufacturing (CIM) more closely. That has proven to be an important step from custom-made to pseudo-standard (configured) software solutions. Within the ISA 95 standard, a subdivision is made between activities relating to production, quality, maintenance and inventory. Depending on the main functionality a Manufacturing Execution System (MES), Maintenance Management System (MMS), Warehouse Management System (WMS) or Laboratory Information Management System (LIMS) can be distinguished (Figure 1).

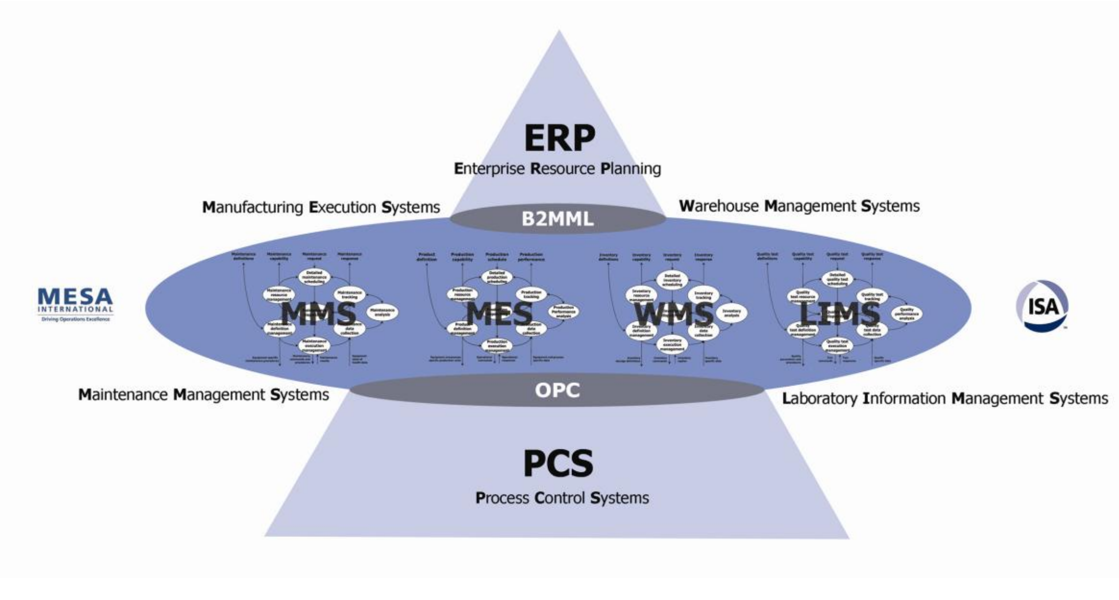

Figure 1: Pseudo-standard software solutions operating within the MOM layer on the different activities: maintenance, production, inventory and quality

However, as one software solution can cover multiple activities, the term MES is generally used to describe the complete software system operating the MOM layer. In this paper, the terms 'MES' and 'MOM software' will be used as synonyms. MOM provides a framework to classify all manufacturing operations, disregarding whether they are performed manually or automated. Not only custom or standard software solutions, but also manual activities and paper or spreadsheet based communication can be mapped.

Initial MES adoption

Contingency theory operates from the assumption there is no "one best way" to carry out a task. The implementation is contingent on a number of factors. Crandall and Crandall (2010) state that contingency theory maintains that one best solution does not exist for even similarly related operations management problems. Instead, the success is contingent on internal factors within the organization, and the manner in which it is implemented. Their work applies the theory to management improvement programs such as JIT, TQM and Six Sigma. In addition, they also refer to the implementation of ERP. ERP systems represent an approach that requires a company to adopt best practices, but not necessarily those best suited to the company, possibly resulting in failure. This reasoning is even more true when considering MOM software implementations (Scholten, 2007). Contingent factors are for example: company size, manufacturing sector, manufacturing strategy and standard operating procedures. Software vendors that configure standard MES solutions usually present results from previous projects to persuade new customers. However, it is important to differentiate between the company that originates the MOM implementation, and the companies that follow later with their own version. The originator is the first company that successfully implements the system. If the followers using the same software solution are also successful, it is most likely because they operate similar to the originators. That explains why most MOM software solutions specialize in specific industries, such as: pharmaceutical, food & beverage, metal, liquid bulk storage, etc. However, when extended into businesses different from the originator, the level of success may vary and, in some cases, the implementation may actually be considered a failure. Contingency theory maintains that managers should match the solution carefully with the needs of the organization. Due to the uniqueness of each MOM 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 MES selection. Consultants and practitioners have developed a number of structured approaches for the selection process, ex. based on the ISA 95 standard (Scholten, 2007).

MOM software innovation

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. In order to enable an incremental adoption, MES must be modular, (re)configurable and flexible. Ultimately, some sort of plug and play system should be achieved. A Service Oriented Architecture (SOA) can facilitate the integration issues (Saenz, 2009).

An issue that haven't yet received the full attention it deserves, is MES change management. No research has been found that describes the post-implementation aspects of MES. This phase represents a significant part of the total cost of ownership of such systems. The real-time character and the link to strategic initiatives make MES susceptible to changes. 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 continuous improvement of MES itself is important to keep the system reliable and to standardize the new way of working (Cottyn et al., 2011).

Continuous improvement

To maintain efficient manufacturing operations under changing circumstances, continuous improvement initiatives are essential. Lean is a philosophy carrying the motto 'Doing more, with less!'. The essence of Lean thinking is specifying value and - by doing so - simultaneously uncovering waste. The initial concept of Lean was extended to five key principles by Womack and Jones (1996): Specify value; identify value streams; make value flow; let the customer pull value and pursue perfection. The ultimate goal is a production process without any of the seven deadly wastes: overproduction, waiting, transport, extra processing, inventory, motion and defects. However, as that situation is impossible to reach, Lean manufacturing is a continuous process towards perfection. Originally, Lean practices were considered to be based on purely manual efforts. The project team starts from scratch and analyses the current situation by walking through the production process. A Lean journey typically starts on a higher level by drawing and analyzing the Value Stream Map (VSM). A number of kaizen (continuous improvement) events determine the required actions (e.g. introduce pull system, increase operator efficiency, reduce changeover time or re-layout the factory floor) to reach the desired future state. There is one significant difference between Kaizen and Innovation: Kaizen does not necessarily call for a large investment in capital to implement the strategy (Terziovski and Sohal, 2000). The continuous improvement concept is driven by the Deming Cycle. This methodology consists of four stages: Plan, Do, Check and Act. The Plan stage consists of studying the current situation, gathering data and planning for improvement. In the Do stage, the plan is implemented on a trial basis. The Check stage is designed to determine if the trial plan is working correctly and if any further problems or opportunities are found. The last stage, Act, is the implementation of the final plan to ensure that the improvements will be standardized and practiced continuously. This leads back to the Plan stage for further diagnosis and improvement. The PDCA cycle can be used to adjust MES to better fit the contingent factors of the manufacturing operations of a specific company.

Role of MES

Wigand (2007) refined Leavitt's diamond model of organizations to analyze the impact of Information Technology (with e-mail as IT example) on structure, people and tasks (Figure 2). He concluded that IT efforts are opportunities to capitalize on creating new ways of working by redesigning tasks, changing the roles of individuals, spanning organizational boundaries, creating new communication paths and social interactions and focusing on the interactivity of these basic components. This model can also be applied to the use of MOM software in production environments. Automating information flows in the MOM layer, can reveal opportunities to further improve manufacturing operations. Benefits can reach further than the initial goal. The extra visibility can lead to additional value creation (AberdeenGroup, 2005). MES, as Information Technology (IT), interacts with the other basic components of the model:

- **The task to be accomplished –** Software support eliminates wastefull activities, imposes standard work to achieve efficient and qualitative production and gives the opportunity to focus on possible improvements.
- **The role of the individual –** Providing operators with real-time visibility and transparency into production performance, manufacturers can ensure that the right people are able to take the right actions at the right time by adding intelligence to the raw data. Operators get empowered to boost performance.
- **The structure of the organization –** By automating information flows, the different activities within a manufacturing environment (production, maintenance, quality and inventory) can be better synchronized. Software support for planning purposes, can be integrated with maintenance requests. Efficient information flow from quality testing ensures qualitative production and limited inventory waiting times before release.

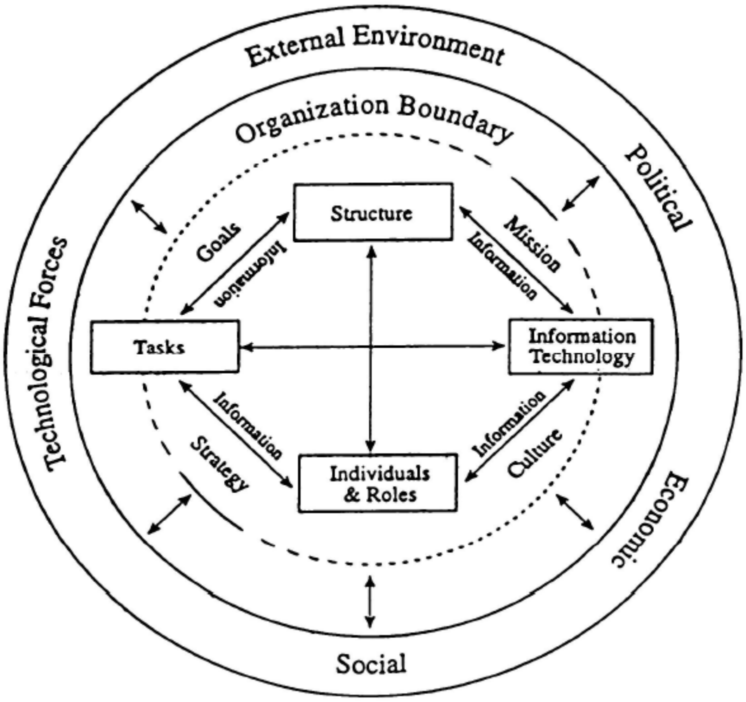

Figure 2: The organizational interaction diamond model (Wigand, 2007)

Accordingly, MES can be an enabler of continuous improvement programs. CDC Factory (2007) lists a number of most common causes of failure. In order to avoid those pitfalls, an efficient implementation of the MOM layer is crucial. MES must incorporate and – even more important – maintain the necesarry software support for MOM.

In figure 3 a stepwise MOM evolution example is given of a small furniture manufacturing company as result of different improvement initiatives. The manufacturing operations performance is given in function of time. The performance measure is merely indicative and can be seen as a combination of quality, cost and delivery information. After each MOM innovation step, a continuous improvement initiative uses the extra visibility to fine-tune the new way of working.

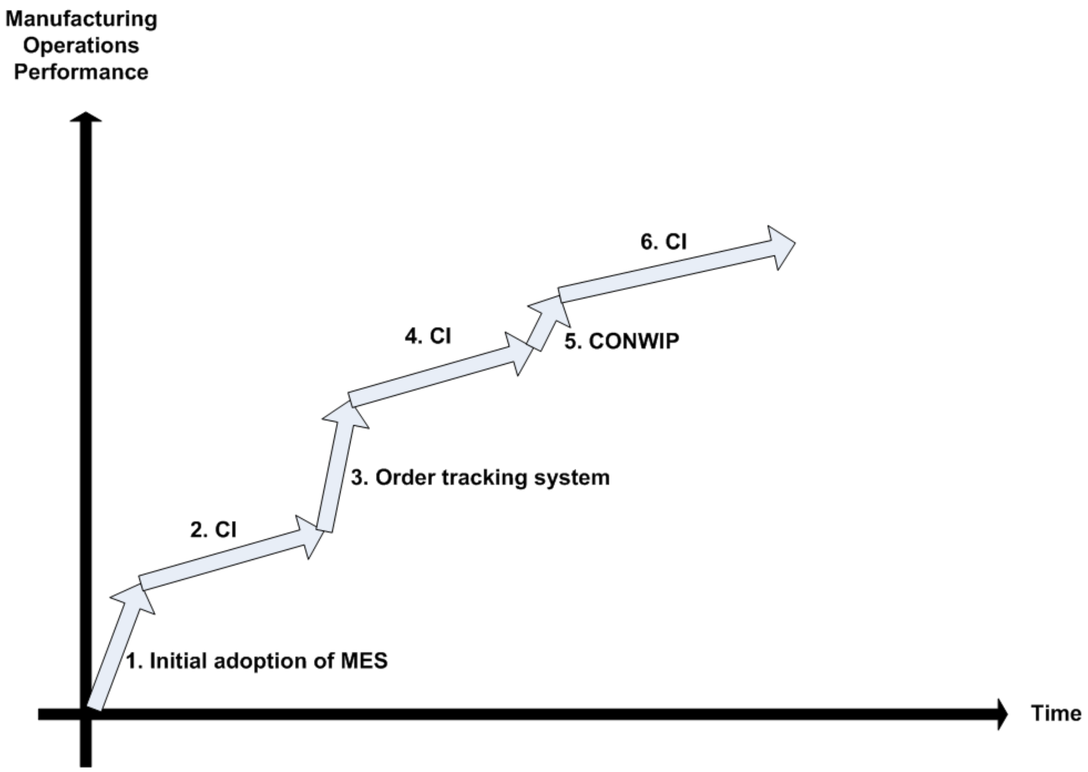

Figure 3: Stepwise evolution example of the manufacturing operations performance as result of different kinds of improvement initiatives

1. **Initial adoption of MES:** Each production activity on an order by an operator is recorded with a barcode scan. The data are necessary to calculate KPI's (number of seats produced, efficiency of employee or work center and leather consumed) and keep track of operator work hours for payment of wages. The support of MES increases the efficiency of the operators (no more manual writing) and the efficiency of administration/manager (no more data collection, entering and structuring in MS Excel).
2. **Continuous improvement:** Based on the historical data available in MES, theoretical production lead times and cost of the different models are gradually fine-tuned. This effort results in a more realistic planning and price setting. A MES functionality is added to monitor the values in the future and provide warnings when theoretical planning and costing parameters deviate systematically.
3. **Order tracking system:** The production manager loses a lot of time distributing and following up production orders. A paperless system is put in place to track orders on the production floor. Operators use touch panels (instead of barcode scanning) to indicate their production activities. Through MES, the production manager can now manipulate the flow of orders on the production floor from his desk.
4. **Continuous improvement:** Based on his experience, the production manager sets up an priority system for waiting orders at each production step. This system replaces the complex and time consuming planning process in MS Excel. The cutting process combines multiple orders consisting of the same leather type. At the end of the production process, priority is based on the region of the customer to realize an efficient transportation plan. Operators see a sorted list on their touch panel that

updates in real-time. Based on ongoing experience, the priority system is further optimized.

5. **Pull system:** In order to reduce the work in process (WIP) on the production floor (and consequently also the lead time), a pull system is introduced. The production manager uses the order tracking system as CONWIP system. He only starts a new production order, when an order is finished. At first, the maximum WIP is held fixed on a relatively high level.
6. **Continuous improvement:** The maximum amount of WIP is gradually being reduced and unbalance, bottleneck, quality and other problems come to surface. This can be the breeding ground for future improvements.

This improvement of manufacturing operations has no end, it's a continuous cycle towards perfection. During each step, the PDCA cycle is used to guide the improvement. The Do and Check phase are mostly calculations and simulations based on the historical data available in MES. Cottyn et al. (2011) propose a method to structure this continuous improvement (Figure 4). The MES functionalities and Lean practices can be mapped onto the same MOM framework for a specific company situation. This makes it possible to check the necessary information flow (support) in between all components during the MOM analysis. By zooming into a certain functionality, the required information flows can be identified in more detail. All information flows consist of standard object models, as defined by ISA 95 part 1, 2 & 3 (ISA, 2000). The available information is standardized to ISA 95 object models to enable a generic MOM analysis. When improvements are reached, MES is changed to impose the new way of working.

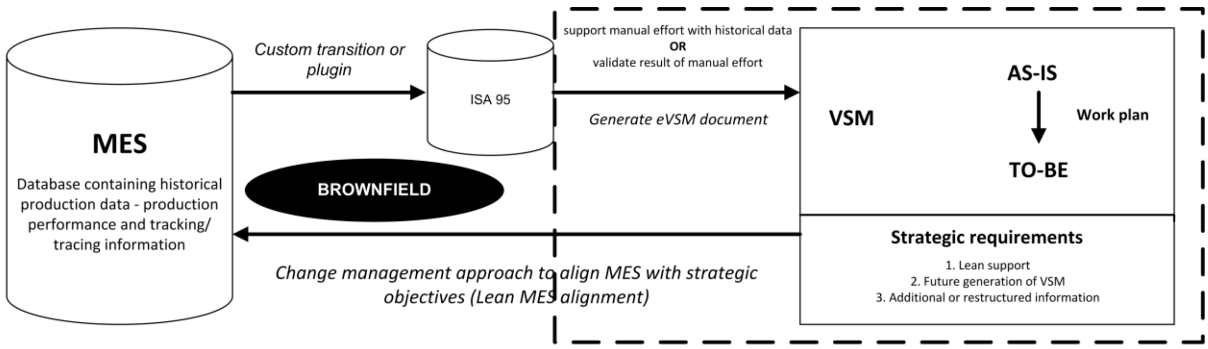

Figure 4: The alignment method between MES and Lean (Cottyn et al, 2011)

CASE EXAMPLE: A FOOD AND BEVERAGE COMPANY

A food and beverage company started a Lean improvement project to optimize manufacturing operations. The main goal is to optimize operator tasks during daily operations. By structuring historical data and through observation, the AS-IS situation is mapped. Starting from the current MOM support, future improvements are analyzed. As the project has suffered some delay, it's too soon to publish any results. For now, the example will only be used to illustrate the dual role of MES during the project. The eventual improvements will be discussed in later stadium.

Current MOM support

The initial adoption of MES was triggered by legal provisions for tracking and tracing purposes. At the same time, a batch tracking system was put in place to enable automatic KPI reporting. Data collection of crucial machine parameters is done automatically. Operators manually enter critical input into MES such as: batch start/stop, machine downtime information, etc. Other information; such as quality test results, cleaning time and packaging material registration; are still manually written down (and archived) on pieces of A3 paper (per shift).

MES supplies historical data

The system contains a lot of production data that can be of use during the improvement cycle. To make the data available within the generic MOM framework, the MES data model is mapped to standard ISA 95 object models (Figure 4). The different process segments are called 'units'. The segment responses are 'batches'. Each unit has some tag values, ex. 'input counter' is the amount of material consumed, 'output counter' is the amount of material produced, etc. It requires an effort to establish the ISA 95 plug-in, but once this translation is done, it can be re-used during future improvement cycles. Standard tools can now make use of the available data to support or validate the analysis. As an example, Cottyn et al. (2011) describe the standard generation steps for an eVSM template of production lines with cycle times, changeover times, waiting times and extra KPI information. Similar attempts could be undertaken to support other Lean tools or continuous improvement initiatives.

Observation

On the other hand, the efficiency of the daily manufacturing operations on the shop floor is considered through observation. The current use of the MES system is evaluated. Important aspects are efficient operator interaction with the data collection module, visual decision support for operator task prioritization and meaningful feedback for operator involvement. What elements must change? What manual or paper based activities could be worthwhile to include in MES? During a limited period of time the project team follows the activities of some operators in great detail. What is the task list of each operator? Each distance, each exchange of information, each activity, each problem is noted down. The experience of the operator can be crucial information. What would he or she do? Findings can be discussed in team meetings and relevant kaizen events launched.

MES controls achieved improvements

The combination of historical data and observation can expose improvement opportunities. A change management approach must be used to make MES control the achieved improvements. The updated MES will – in turn – supply information to support future improvement analysis. This enables the continuous evolution of MOM.

CONCLUSION

Filling the gap in between administration and production is not a trivial task. The main goal is to achieve a digital information exchange instead of manual, paper or spreadsheet based communication. Nowadays, efficient manufacturing operations without software support has become unthinkable in many cases, due to legal provisions, high product mix, etc. 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. Automating information flows in the MOM layer, can reveal opportunities to further improve manufacturing operations by continuous improvement initiatives. Benefits can reach further than the initial goal of automating information flows. The extra visibility can lead to additional value creation. The case of a furniture manufacturing company is explored as an example of the manufacturing operations performance evolution over time.

The term MES is generally used to describe the complete software system operating the MOM layer. Accordingly, MES can be an enabler of continuous improvement programs. Through a case study in a food and beverage company, the dual role of MES during a Lean improvement project is illustrated: supporting the change process with historical data and controlling the achieved improvements.

As the project has suffered some delay, the food and beverage case is still work in progress. Further research has to be done on a change management approach for MES that facilitates the model state changes as result of typical Lean transformations.

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