# MES Support for Lean Production

Daryl Powell, Andreas Binder, Emrah Arica

# MES Support for Lean Production

Daryl Powell[1,2*], Andreas Binder[3], Emrah Arica[1,2]

[1]Department of Production and Quality Engineering,
Norwegian University of Science and Technology, Trondheim, Norway
{daryl.j.powell, emrah.arica}@ntnu.no
[2]SINTEF Technology and Society, Trondheim, Norway
{daryljohn.powell, emrah.arica}@sintef.no
[3]Department of Production Systems and Logistics,
Leibniz University, Hannover, Germany
andy_binder@web.de

**Abstract.** In the traditional sense, IT has often been viewed as a contributor to waste within lean production. However, as the business world changes and competition from low-cost countries increases, new models must be developed which deliver competitive advantage by combining contemporary technological advances with the lean paradigm. In order to make a contribution within this field of research, we evaluate the support functionality of Manufacturing Execution Systems (MES) for lean production. We address the fundamental principles of lean production and compare them to the functionality offered by MES, and by combining existing theoretical contributions with practical insights we develop a five-stage capability maturity model for MES support for lean production.

**Keywords:** Lean Production, Manufacturing Execution System, Production Control

## 1 Introduction

Though the theory of lean production is nowadays well understood, the relationship between information technology (IT) and lean production remains a controversial and far less explored topic. While lean is often characterized by decentralized coordination and control, IT is typically best suited to support centralized production planning. However, more recently, IT is being used more and more as an enabler of decentralized decision making. For example, Powell and Strandhagen [1] explore the lean-ERP paradox, and suggest that there is a synergistic impact to be realized in combining ERP systems with the lean paradigm. For example, Powell et al. [2] introduce a capability maturity model for ERP support for pull production. Whilst Riezebos et al. [3] argue that modern IT can indeed be tailored to support lean; further research is required to investigate the combination of lean production principles and other modern applications of IT, such as manufacturing execution systems (MES). Therefore, the purpose of this paper is to evaluate the support functionality of MES for lean production by addressing the following research question: *How can MES be used to support lean production principles?*

## 2 Theoretical Background

The term lean production was popularized by Womack et al. [4] when they compared the mass production principles of the Western world to the very simple production principles of Toyota. As such, Lean production is based on the principles and working processes of the Toyota Production System, and has been defined as doing more with less [4]. In its simplest terms, lean production can be described as the elimination of waste [5]. Liker [5] suggests that the goals of lean production are highest quality, lowest cost, and shortest lead time. It was however Womack and Jones [6] who provided the world with a vision of what lean is about, and summarized lean thinking as five principles: precisely specify value by specific product; identify the value stream for each product; make value flow without interruptions; let the customer pull value from the producer; and pursue perfection.

However, the lean philosophy has so far been primarily directed at the organization and less on information technologies [7]. As such, IT has since been viewed as a contributor to the waste to be eliminated, rather than as a tool to help achieve and sustain positive change [8]. The increasing rate of development of IT today is constantly increasing manufacturing companies' ability to react quickly and reliably to demand through increased transparency, visualization and processing capabilities. Moody [9] suggests that, although profitability can be enhanced in any number of ways, one of the most rewarding and direct avenues is through the use of technology.

As an example of modern developments in IT, Arica and Powell [10] assert that Manufacturing Execution Systems (MES) are a highly plausible integration mechanism for linking the more traditional ERP systems to the production activity which occurs on the shop floor, which is where Lean efforts have traditionally been focused. As such, the application of MES has today become a very popular approach to the integration of manufacturing planning and control tasks, and has been applied in various types of industry. Though MES has emerged from the process industry, these types of execution system have more recently begun to be applied in discrete product manufacturing [11].

Though several authors attempt to analyze MES in terms of its complementarity for Lean efforts [e.g. 12, 13], so far an effort has not been made to establish a capability model for MES support for Lean Production. Therefore, by combining the approaches of Powell et al. [14] and Powell et al. [2], we use the five lean principles [6] in order to construct a capability model for MES support for lean production using both theoretical and practical insights.

## 3 Research Methodology

The primary research methodology is literature review. We analyze extant literature in the form of international journal publications, scientific textbooks, and white papers in order to explore the potential support functionality of MES for lean production. We systematically operationalize the five lean principles of Womack and Jones [6] in order to develop a framework and capability model for MES support for lean production. We also take insights from a practical, "illustrative" case study, which we have selected through convenience sampling. The case company is a Norwegian producer of jet engine components. The case study is conducted using data collected through semi-structured interviews of several informants in the company, including the production manager and production engineers. Direct observations and the analysis of secondary sources, such as company documentation and corporate website are used for triangulation, to check the internal consistency of data [15]. In this process a theory building approach is adopted to identify the potential support functionality of MES for lean production principles.

## 4 MES Support for Lean Production

In order to assess the depth of support provided by MES for lean production, we first conceptualize a capability maturity model (CMM) for the use of MES to support lean production principles. We consider existing capability maturity models [2, 16-18] in order to propose the various levels that should be contained within such a model. Then, by operationalizing the five lean principles with practical examples, we propose example criteria that a producer should fulfill in order to achieve each level of the capability model.

### 4.1 Capability Maturity Model

A maturity model gives a company the opportunity to compare the maturity of its operations relative to an industry best practice [19]. Furthermore, this tool supports the IT management in deriving and prioritizing improvement measures and subsequently controls the progress of their implementation [22]. All in all, a maturity model consists of a sequence of maturity levels for a class of objects that last from a bottom stage, which represents initial states e.g. characterized by an organization having little capabilities, up to the highest stage of total maturity [20]. Hence the developed capability maturity model (CMM) should provide the manufacturers with a framework to assess the support from their MES for the different levels of Lean Thinking. It delivers a five level scale for the maturity of the MES support within a company. Additionally, the manufacturers gain the opportunity to compare their maturity with each other and thus to identify the company's position compared to its best-in-class competitors, for example.

Several maturity models have been developed in the field of IT systems. The models listed in Table 1 have been considered during the development of our CMM. The IT balanced scorecard (BSC) maturity model deals with the use of the mentioned BSC regarding the measurement and improvement of present IT solutions. The CMM for Lean maturity and Lean sustainability provides a framework to distinguish the progress of the company regarding the maturity of the Lean implementation. It starts from the bottom stage of sporadic production optimizing to the top stage of a Lean execution beyond the own enterprise [17]. The capability maturity model integration (CMMI), developed by the Software Engineering Institute, focuses on improvements to the software process to ensure that they meet business needs more effectively. It can be considered as a framework to assist an organization in the implementation of best practice in software and systems engineering [18]. The last of the four considered capability maturity models deals with a topic closest to the present one. This model defines a scale for evaluating the maturity level and the extension of an organization's use of the ERP system to support Pull Production [2]. A summary of the models considered is given in Table 1.

| Author | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|---|
| Powell et al. [2] | Initial | Planned | Validated | Controlled | Optimizing |
| Van Grembergen et al. [16] | Initial | Repeatable | Defined | Managed | Optimizing |
| Jørgensen et al. [17] | "Sporadic…" | "Basic…" | "Strategic…" | "Proactive…" | "Extended…" |
| O'Regan [18] | Initial | Managed | Defined | Quantitatively managed | Optimizing |

**Table 1.** Summary of Capability Maturity Models considered

Our CMM (Fig. 1) aims to classify the maturity of MES support for the five Lean principles [6]. Since it is recommended that the Lean principles be implemented in sequence, these principles directly represent the different stages of the maturity model. Though we place particular emphasis on the CMM for Lean maturity and Lean sustainability [17], we do however suggest that the extension of Lean practices beyond the enterprise can be achieved earlier then in level five, for example as early as level three (defined - flow). As it is the support functionality for MES for lean that we are most interested in, we take most insight from the CMM of Powell et al. [2]. A selection of examples of supported lean techniques for each of the five levels can be seen in Fig. 2.

## 5 Case Study: Volvo Aero Norge

This case study presents work from the research program SFI Norman. Part-funded by the Norwegian Research Council, SFI Norman aims at securing the future of Norwegian manufacturing through innovative working practices. The case itself draws on insight from Volvo Aero Norge (VAN) by comparing the company's current use of MES in light of our capability model.

VAN is an industrial partner organization within the SFI Norman program. Located in Kongsberg, Norway, VAN manufactures jet engine components for the world's largest aircraft engine manufacturers. The company is a technological competence center within advanced, mechanical production. This paper considers production operations at the Kongsberg plant, with a focus on production control.

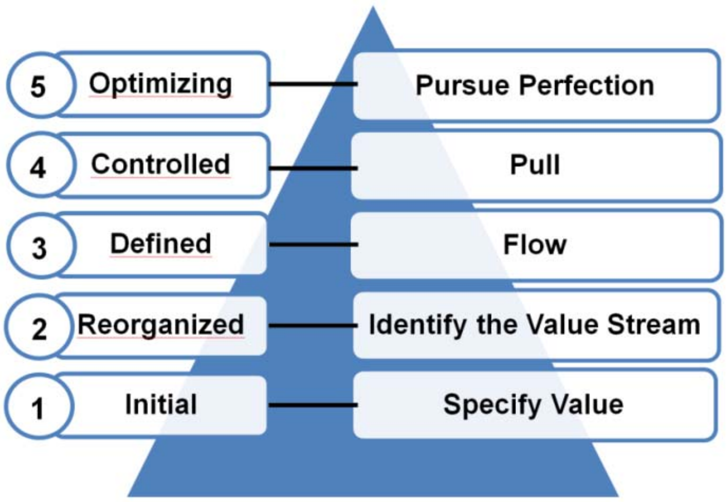


**Fig. 1.** CMM for MES support for lean production

### 5.1 Production Control at VAN

In this section we describe the production control activities at VAN. Firstly it should be duly noted that detailed scheduling of jobs to the resources is not carried out. Instead, dispatching of jobs is based on the First-In-First-Out (FIFO) principle. The dispatcher needs to consider and control all possible constraints in this highly complex manufacturing cell environment, which means traditional lean production control (with fixed schedules) is not ideal for VAN. A less myopic approach is therefore required. Also, as VAN have to meet the demands of the company's global objectives (e.g. reduction in WIP and lead-times), when work is released to the shop floor, information is needed to track the location and progress of the work during the entire production process. The status of the machines is automatically updated but some other activities require human intervention and paper work to update the information in the shop floor.

Information is collected from the shop floor in two ways. When the order is released to the resources its status is updated with the use of bar-code technology. This data is collected manually. The second way of data collection is carried out by tailor-made Manufacturing Execution System (MES), so called Machine/Cell Supervisor (MSUP/CSUP) that provides the control of the cell's operations and allows the visualization of all information needed to keep continuity in the production activities in terms of resources and equipment. The real time information is updated in a database and the resource status is displayed on screens on each of the machines on the shop floor.

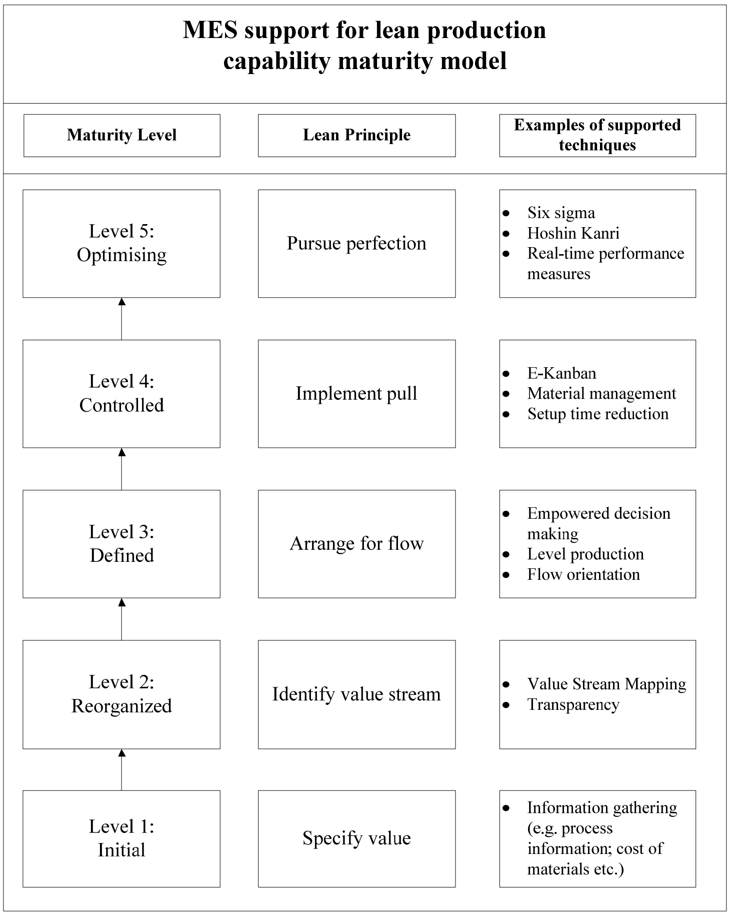


**Fig. 2.** Examples of supported techniques for each level of the CMM

The MSUP units that are installed on each machine provide a number of functions. Firstly, it forwards operational data from the ERP system (SAP) to each of the machining stations, and controls the machine start and internal transportation in the machines based on tooling status and availability, as well as the latest start date found within the ERP system. Additionally, it shows the status of the machine resources (e.g. machine, pallet, tools), and highlights any error messages that may occur. All MSUP units store status information in an MS SQL database, which is also accessed by the Cell Supervisor (CSUP). The CSUP then gives an overview of the entire production floor based on the status information from each individual MSUP.

### 5.2 MES Support for Lean Production at VAN

We applied our capability model to operations at VAN in order to gain practical insights into its applicability. From discussions with representatives at the company and through our own observations, we suggest that the current state of operations at VAN represents a level three in our CMM. For example, MSUP is providing useful process information to operations personnel (Level One); and the CSUP uses this information for the transparency of processes (Level Two). By providing an overview of processes, the MES at VAN can be used to identify the value stream by aiding Value Stream Mapping (VSM) activities and can also assist in waste identification such as time spent waiting in- and between machining operations. More importantly, MSUP/CSUP can be used for decision making tasks, providing the information required to maintain flow of operations through level production (Level Three).

In terms of its applicability, we suggest that the CMM has proved to be very useful in helping to identify improvement opportunities at VAN. For example, related to the information gathered by the current CSUP system, a need for more detailed production status information has been identified. More detailed information regarding machining time, current machine status, detailed view of various key performance indicators (KPI) such as Overall Equipment Efficiency (OEE), and perhaps a simple way to generate new KPIs based on all status information is seen to be beneficial in the production. We also suggest that the CSUP and MSUP system can be used to effectively deploy pull production principles in a high-tech environment.

## 6 Conclusion

In this paper, we set out to investigate the support functionality of MES for lean production. Having first posed the research question "How can MES be used to support lean production principles?" we developed a capability maturity model (CMM) that highlights such support functionality, and which can be used by both researchers and practitioners for the future integration of lean production and information technology. Therefore, we suggest that our CMM has a significant impact for theoretical knowledge and practical application; and also further developments in the field of lean and IT.

Further work should apply and test the CMM in other industrial settings, in order to test its generalizability. By applying our model to other cases, we suggest that a more generalized approach to improvement through the deployment of our CMM can be realized.

## 7 References


[1] D. Powell and J. O. Strandhagen, "Lean Production Vs. ERP Systems: An ICT Paradox?," Operations Management, vol. 37, pp. 31-36, 2011.

[2] D. Powell, J. Riezebos, and J. O. Strandhagen, "Lean production and ERP systems in SMEs: ERP support for pull production," International Journal of Production Research, vol. Available online 23 January 2012, 2012.

[3] J. Riezebos, W. Klingenberg, and C. Hicks, "Lean Production and information technology: Connection or contradiction?," Computers in Industry, vol. 60, pp. 237-247, 2009.

[4] J. P. Womack, D. T. Jones, and D. Roos, The Machine that Changed the World. New York: Harper Perennial, 1990.

[5] J. K. Liker, The Toyota Way: 14 Management Principles From the World's Greatest Manufacturer. New York: McGraw-Hill, 2004.

[6] J. P. Womack and D. T. Jones, Lean Thinking: Banish Waste and Create Wealth in Your Corporation. New York: Simon and Schuster, 1996.

[7] D. Zuehlke, "SmartFactory - Towards a factory-of-things," Annual Reviews in Control, vol. 34, pp. 129-138, 2010.

[8] S. Bell, Lean Enterprise Systems: Using IT for Continuous Improvement. Hoboken, NJ: Wiley and Sons, 2006.

[9] P. E. Moody, "With Supply Management, Technology Rules!," Supply Chain Management Review, vol. May/June 2006, 2006.

[10] E. Arica and D. Powell, "ICT Integration for Automatic Real-time Production Planning and Control: A Concept Note," presented at the APMS 2010: International Conference on Advances in Production Management Systems, Cernobbio, Como, Italy. 11-13 Oct 2010, 2010.

[11] J. Kletti, Manufacturing Execution Systems-MES: Springer Verlag, 2007.

[12] J. Cottyn and H. V. Landeghem, "The Complimentarity of Lean Thinking and the ISA 95 Standard," presented at the WBF 2008 European Conference, Barcelona, Spain, 2008.

[13] T. Gerberich, Lean und MES-Widerspruch oder Synergie?: GABLER, 2011.

[14] D. Powell, E. Alfnes, J. O. Strandhagen, and H. Dreyer, "ERP support for lean production," presented at the Advances in Production Management Systems. Value Networks: Innovation, Technologies, and Management. Proceedings of the IFIP WG 5.7 International Conference, APMS 2011, Stavanger, Norway. 26-28 September 2011, 2011.

[15] T. A. Scandura and E. A. Williams, "Research methodology in management: Current practices, trends, and implications for future research," Academy of Management Journal, pp. 1248-1264, 2000.

[16] W. van Grembergen and R. Saull, "Aligning business and information technology through the balanced scorecard at a major Canadian financial Group: its Status Measured with an IT BSC Maturity Model," presented at the Proceedings of the 34th Hawaii International Conference on System Sciences, 2001.

[17] F. Jørgensen, R. Matthiesen, J. Nielsen, and J. Johansen, "Lean maturity, lean sustainability," Advances in Production Management Systems, pp. 371-378, 2007.

[18] G. O'Regan, Introduction to Software Process Improvement London: Springer, 2011.

[19] T. H. Netland and E. Alfnes, "Proposing a quick best practice maturity test for supply chain operations," Measuring Business Excellence, vol. 15, pp. 66-76, 2011.

[20] J. Becker, R. Knackstedt, and J. Pöppelbuß, "Developing maturity models for IT management," Business & Information Systems Engineering, vol. 1, pp. 213-222, 2009.