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# Manufacturing system lean improvement design using discrete event simulation

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**Abstract**

Lean manufacturing (LM) has been used widely in the past for the continuous improvement of existing production systems. A Lean Assessment Tool (LAT) is used for assessing the overall performance of lean practices within a system, while a Discrete Event Simulation (DES) can be used for the optimization of such systems operations. Lean improvements are typically suggested after a LAT has been deployed, but validation of such improvements is rarely carried out. In the present article a methodology is presented that uses DES to model lean practices within a manufacturing system. Lean improvement scenarios are then be simulated and investigated prior to implementation, thereby enabling a systematic design of lean improvements.


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*Keywords:* Lean manufacturing; lean assessment; discrete event simulation

## 1. Introduction

Lean manufacturing (LM) practices are embedded in five core principles: i) determining the value of each specific product in the eyes of the end client; ii) identifying the value flow of each product; iii) making the value flow continuously; iv) letting the customer pull value from the manufacturer and v) seeking perfection [1]. Ensuring Continuous flow of the product within the manufacturing system supports the principles lean. A collection of lean practices such as just in time (JIT) supplier management, quality management (QM), Total Productive Maintenance (TPM), Lot Sizing, Leadership Commitment, Employee Involvement, Setup Reduction, Teamwork, Customer Engagement and many others make up a LM system.

Assessing the overall performance of lean through lean practices is typically done using a lean assessment tool (LAT). Various models have been applied as the basic structure of many LATs [2], such as Value Stream Mapping (VSM), Lean Enterprise Self-Assessment Tool (LESAT), Benchmarking, Lean Index and the Strategos LAT. Others have been used as the basis for a lean assessment audit [2]- European Foundation for Quality Management and the Shingo Model. The uses of most lean audits and LATs have focused on two primary areas: a) assessing and benchmarking lean performance and b) identifying practices that should be the focus of improvement efforts [2]. Rarely are the lean audits used for investigating what the likely effect would be if the lean improvements were implemented [3]. So while the LATs would have identified which lean practices to improve and possibly how to improve them, little is known about how the proposed lean improvements will behave in reality. For example a lean assessment may identify JIT Supplies as one of the weak performing lean practices because raw material supplies are often delayed. The logical recommendation would be to reduce the supply lead-time, preferably to the "leanest" level possible, say zero minutes. While this is an improvement in the right direction, knowledge is still required as regards the effect this improvement will have on other lean indices and on the whole system. This knowledge is sought for two reasons. Firstly lean practices interact with one another and so there would likely be trade-offs in their improvements. Secondly an optimum level often exists beyond which further lean improvements do not have significant effect on the system- a waste in lean parlance.


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For example, [4] found an optimum Kanban capacity in a manufacturing case, and increasing the capacity beyond the optimum level did not correspond to a significant increase in throughput. So in our above example with the supplier lead-time, it may be that the optimum raw material-delay is 30 minutes and going below this may not improve overall lean performance; meanwhile there may be additional cost implications going further. Majority of LATs used in the literature do not validate lean transformations before implementation [3].

The current study is motivated by the need to provide an objective approach to identify the extent of lean improvements after a lean assessment. Meanwhile [5] attempt to investigate this but their methodology was cost/budget-based. It is proposed in this article to advance an objective and quantitative based approach for predicting the likely impact of improvements in lean practices, and one way to achieve this is through discrete event simulation (DES) modeling. For the purpose of describing the approach, ensuring continuous flow within manufacturing system is the focus of the analysis.

## 2. DES modeling and lean assessment

DES is useful for gaining an in-depth understanding of a system to improve its performance. The DES software models distinct sequence of state changes that occur in time. In order words any system that involves a process flow where events change in time sequences can be simulated, for example a work item that flows through a manufacturing system. In a manufacturing system, the model takes into account the work items, resources and activities used in processing work items, their interactions and the constraints. Model objects (work items, resources, activities etc.) are configured (using input parameters such as work item inter-arrival times, work item routings, and activity processing times) in the DES to mimic the real system. Running the DES model establishes important details that may be otherwise concealed in the real system. In addition, experiments can be performed with the model, rather than with the actual system, and eliminate the need for costly real life experiments for example. These and other advantages of DES modeling have encouraged its use in lean related improvements.

There are previous works where DES modeling has been used to support lean system analysis [3,4,6,7]. Industrial cases have also been reported [see www.lanner.com; www.arenasimulation.com; www.simul8.com]. These and other DES/lean assessment studies have tended to focus on assessment by key performance indicators (KPIs) such as lead-time, Overall Equipment Effectiveness and works in progress (WIP). Yet, modeling lean practices is possible within the various building blocks of most DES software, such that the simulation can be used to provide information about the effects of altering and improving lean practices, while considering the trade-offs that exists between them. There is in fact more to DES/lean assessment relationship than just lean KPI analyses.

## 3. Problem definition and proposed methodology

Typically after a lean assessment is done, the next logical step is to improve lean, as the assessment would have indicated the directions of lean improvement through the weak performing areas. However, according to [3]

> *"A traditional lean transformation process does not validate the future state before implementation, relying instead on a series of iterations to modify the system until performance is satisfactory"*

The above statement is true for majority of lean assessments that have been reported in the literature. The LESAT and other questionnaire-based (such as the Shingo Model and EFQM) lean assessment audits are typical examples. For example the LESAT is an audit questionnaire for self-assessing the performance of the current lean state of an organization vis-à-vis a desired lean state. Both current and desired levels are scored on a scale of 1 to 5 for a list of 54 lean practices, where 1 represents very limited awareness and use of lean practices and 5 represents recognized best lean practices [8]. Lean performance for the system is based on the gap between the current and desired levels of performance. The LESAT assessment indicates areas with substantial opportunities for growth (i.e. those with wide gaps) as well as areas for low perceived potential for growth (i.e. those with minimal gaps) [8]. The LESAT and other audit-based LATs share one deficiency: they do not validate the desired lean state. Analytical-based LATs have not been used to overcome this deficiency either, as majority of previous research works have not validated the future lean state.

[3] have proposed the five step simulation-enhanced approach to implementing LM (Fig. 1). The typical LAT such as VSM would cover steps 1 to 3. The focus of the current article is to look more closely at Steps 3 and 4 i.e. the future state design and validation. The proposed approach in the current article is summarized in Fig. 2.

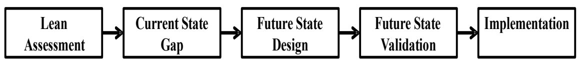


Fig. 1 Simulation-enhanced approach to lean manufacturing [10]

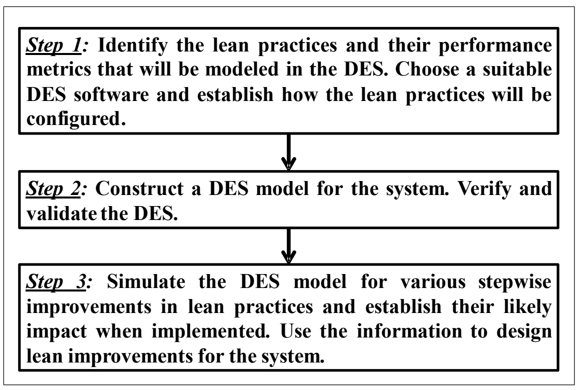


Fig. 2 Methodology steps describing the proposed approach for future state design and validation