How Lean transformation affects scheduling

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ABSTRACT

The Lean paradigm transforms a production company from utilisation-centric planning into a system in which other operating conditions such as short flow times, local control, reduction in variation, and first-in-first-out control are weighted as well. This paper studies how the scheduling of production changes when the above four conditions are implemented. Their effects are studied by constructing an optimisation model for the scheduling of a flow shop. The optimisation model is based on the following ideas. First, when the flow time is emphasised, the objective of the scheduling changes from utilisation to a short flow time. Second, if local control is used, it means that the optimisation is performed locally, i.e. individually at each station, and it concerns the makespan at the station. Third, if the variation is reduced, the processing times and arrival times have less variation and, fourth, the scheduling can force the flow times to have less variation by using first-in-first-out (FIFO) sequencing. The experimental results achieved using the model describe how and in which order the operating conditions under study should be implemented in the scheduling. For example, if utilisation is important, local control and FIFO should not be used before variation is reduced.

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1. Introduction

When companies undergo Lean transformation, they start to use different techniques, such as Single Minute Exchange of Die (SMED), Kanban, Kaizen, and Heijunka, to streamline their production. Different Lean techniques affect production through different mechanisms. These mechanisms can be grouped on the basis of the type of effect they have on the operating principle of the system and operating conditions. Some methods focus on reducing flow time, some increase the flexibility of the production, e.g. by using local control, and some permanently reduce disturbances and thus variation. The purpose of this paper is to study how these methods should be used when scheduling is considered. The paper is a revised and extended version of a conference paper [1]. In this extended version, the content is updated and, in particular, the numerical experiments section is made broader so that it now studies the usefulness of Lean methods in the case of different numbers of jobs and machines.

In the literature, it is often emphasised that all the Lean techniques should be used if Lean is applied, or otherwise production does not improve significantly. Focusing on just a single technique is often seen as the main problem in Lean implementation (see e.g. [2, p. 10]). However, it might be that some techniques are more relevant than others because of the way they change operating conditions and consequently different measures of performance. For example, the Toyota production system, on which Lean is based, has two pillars, which are automation (i.e. smart automation) and just-in-time [3, p. 77]. As described in Ref. [2, p. 32], these pillars stand on stability, which is the foundation for all the other methods. Above the pillars, there are the targets: costs, delivery times and quality. Fig. 1 illustrates this so-called House-of-Lean. In other words, the figure shows that variation should be reduced first, and only after that can the processes be automated and the material flow balanced. Following these ideas, this paper tries to find out how important different operating conditions are when the scheduling of a flow shop is considered. The emphasis is put on finding out what kinds of changes to operating conditions are required and in which order they should be implemented when a Lean transformation occurs.

Lean itself is a buzzword that combines multiple ideas that aim to reduce waste in production. As stated by Likier [2, p. 20], many ideas come from the pioneering work done by Ford [4] and Ohno [5]. Lean has been studied quite extensively during the last few decades (see e.g. [6]). However, as recently reviewed by Powell et al. [7], studies describing a sequential process for Lean implementation, which is in focus in this paper, are at least scattered if not few. One such study, by Åhlström [8], concludes, on the basis of a case study conducted at a Sweden-based company, that management should put simultaneous effort into all aspects of production, beginning with the quality issues, and then, after the quality issues are resolved, the managers should shift to the continuous improvement initiatives. This is related to the original

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The paper is organised as follows. Section 2 first discusses how the four operating conditions studied, i.e. flow time, local control, variation reduction, and first-in-first-out (FIFO) control, relate to Lean techniques, and second, describes an optimisation model constructed to study the effect of these operating conditions on flow shop scheduling. In Section 3, the model is used in numerical experiments to study how the weights on the operating conditions affect the performance of the scheduling. The results are discussed in Section 4, and they suggest that if the utilisation is important, flow time can start to be reduced immediately, local control only when the process is somewhat stable, and FIFO control only if the processing times of the process are stable. Finally, Section 5 presents final conclusions.

2. The Lean operating conditions in scheduling

2.1. Lean techniques and operating conditions

Our paper studies four types of operating conditions that lie behind the use of Lean techniques. These are short flow times, local control, variation reduction, and first-in-first-out (FIFO) control. When a Lean transformation takes place, these four operating conditions are realised at the planning level. Next, we point out how these operating conditions are achieved using different Lean techniques. A more complete analysis of Lean techniques, or actually the techniques in its predecessor philosophy JIT (just-in-time), has been performed by Barlettazzghi and Turco [19].

The first operating condition to be studied, short flow time, is achieved in Lean by limiting work-in-process (WIP), reducing batch sizes, and increasing capacity. First, limiting WIP reduces flow time in production. In production where utilisation is high, it is almost impossible for an increase in WIP to increase throughput without increasing the flow time. Thus the opposite is also true. If the utilisation is high, a decrease in WIP will reduce the flow time.

An example of a Lean technique that reduces WIP is Kanban, a control system based on cards that start the production and are released from the downstream of the production. It reduces WIP by limiting the number of parts in process to the number of the cards. A second way of reducing flow time is reducing lot sizes. For a single machine, if there is a batch of N items and setup time S and processing time t, the flow time is Nt + S. One-piece flow could reduce the flow time in this case. However, it increases the need for setups, which have to be shortened in order to be efficient. This is achieved in Lean by using the SMED (Single Minute Exchange of Die) technique. A third way to reduce the flow time is to have extra capacity or more flexible capacity. This reduces the flow time, simply because the capacity is available.

The second operating condition that is studied, local control, allows simplified decentralised production control. This is not a very new idea as locally applied solutions are often used in practice. The problem with local control is that it might impair the overall control of the production. This is often seen in a functionally working company, where the utilisation of single machines is important, but the whole picture is not so clear. However, the production controllers usually push global targets, and thus may find local control secondary from their point of view. Kanban and 5S are examples of Lean methods that are typically implemented just approached using a mixed-integer linear programming (MILP) optimisation model and optimising it using CPLEX optimisation tool. In the numerical experiments, number of different scenarios are generated, each scenario is optimised separately and average results are studied. This is better way than stochastic optimisation as in the reality the processing times are often known or at least they can be estimated. Complete optimisation is used instead of heuristics such as genetic algorithms or simulated annealing.

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