

Identifying Constraints in Available Production Capacity

*An analysis from a production scheduling perspective of a processing facility
at Sandvik*

Kristin Egerström & Louise Landin

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Department of Production Management
The Faculty of Engineering, Lund University

Accurate production scheduling is an essential element to obtain high performing manufacturing facilities. By optimally allocating the available resources in a factory, improved equipment utilization, and hence production efficiency, can be reached. It is important that the planning considers factors that potentially restrict the available capacity, to access an uninterrupted process flow in the manufacturing workshop. This paper summarizes the master thesis project performed at Sandvik during spring 2020, with the purpose to identify all limiting factors in terms of available equipment, in a processing facility for cast iron details. The analysis showed that three parameters are potential constraints for the available production capacity. However, if the scheduling is done according to these factors, it will be possible to avoid overlaps while maintaining enough capacity to produce forecasted orders. This result thus establishes that there is no need to perform further investment analysis to increase the capacity of any constraint.

Introduction

Context

Production scheduling is used to allocate resources and process flows in manufacturing facilities, in order to meet the prevailing performance criteria. An efficient planning tool is especially important in complex scheduling situations, such as when resources are shared, and synchronization of operations is needed [1]. Factors that limit the output of a production system, so-called constraints, should be handled by an efficient scheduling tool to alleviate the negative impacts that these factors carry. With properly identified constraints, such a tool can facilitate capacity optimization in the production workshop [2].

Background

The Sandvik AB plant in Svedala manufactures stone crushers for the mining and rock industry. The site includes several workshops that specialize in different parts of the production. In this project, the factory in focus is the processing facility West, which machines a large variety of cast details that later are assembled to complete stone crushers.

There are six vertical CNC machines in West, which are all examined in this study. These machines perform various machining processes, such as drilling, milling, and turning. To perform these operations, the machines must be rigged with external CNC tools and other machining

equipment. Due to cost benefits, this gear is often shared between multiple machines, which hence restricts the production capacity. This, since it is not possible to simultaneously produce articles that require the same piece of equipment.

Complications arise as it is not completely established which parameters constrain the available capacity. The existing scheduling program assumes that each machine is fully equipped with all the necessary gear. Also, the program lacks knowledge concerning which articles require the same production equipment. This entails a risk for planning multiple production orders at the same time, although these can not be produced concurrently.

To optimize the sequencing of production orders in West, a new scheduling tool is planned to be implemented during spring 2020. This scheduler will take into account the existing constraining parameters and plan accordingly. It is hence necessary to identify all factors that could limit the available production capacity, in terms of tools and machining equipment.

Purpose

The main purpose of this project is to identify all factors that potentially restrict the production capacity of the vertical CNC machines in West, as well as to examine how they affect production efficiency. A second purpose of this thesis is to provide a recommendation to the company on how to reduce the negative impacts of these constraints.

Methodology

The methodology used in this project was developed based on its primary research objectives, which were to perform a study with problem-solving, descriptive, and exploratory elements. For such characteristics, two suitable data collection techniques are interviews and archive analysis [3].

There are several possible approaches when preparing to conduct interviews. The interview styles can be divided into three categories, namely unstructured, semi-structured, and fully structured [4]. In unstructured interviews, the questions are asked as broad and general concerns. The more structured an interview is, the more specific are the questions as well as the outline of the questionnaire. A semi-structured interview allows both improvisation and deeper exploration of a subject while ensuring that all questions have been covered [5]. In this project, both unstructured and semi-structured interviews were carried out.

Archival data concerns documentation that exists independently from the specific research and for other reasons than to be used in the ongoing study. It is thus important to carefully validate the data and examine its relevance for the project [3]. The archive analysis performed in this study was based on various technical documentation in West, such as data extracted from the machine surveillance program RS Production and the ERP system Infor M3.

Theoretical References

Manufacturing Strategy

To understand a facility's need for production scheduling, it is important to recognize its type of manufacturing strategy. A process choice describes how resources should be organized around a manufacturing process to best fit the product it produces [6]. Batch processes are the most common process choice in manufacturing organizations. They are characterized as disconnected line flows, where moderately complex work and shared resources are common. These resources often complicate the scheduling, as the operations where they are used can not overlap [2].

Single Minute Exchange of Die (SMED) is a Lean production method focused on reducing waste in

a manufacturing process by minimizing changeover times [7]. The main idea behind SMED is to reduce the changeover times by converting internal operations to external. Internal operations refer to tasks that need to be performed when the machine is not running. External operations can, on the other hand, be completed while the machine is running. Since external activities can be prepared while a machine is still operating, they make the process more effective.

Performance Measurement

Overall Equipment Effectiveness (OEE) derives from the Total Production Maintenance (TMP) concept. The main object of TMP is to increase equipment productivity by achieving zero breakdowns and zero defects related to equipment [8]. OEE is a way of measuring this by identifying losses that reduce equipment effectiveness. These losses are defined as activities that occupy resources but create no additional value [9].

Theory of Constraints

Theory of Constraints (TOC) is a systematic management method used to manage constraints that disrupt an organization's progress towards a goal [2]. The method outlines a process for identifying and relieving constraints and helps increase organizations' profits by making materials flow rapidly through entire process systems. A bottleneck is a type of constraint whose available capacity limits the organization's ability to meet the required production volume.

Empirical Study

In West, the six vertical CNC machines are classified into two machine groups, named U6 and U8. In each group, there are three machines. All machines are of the same design, but vary in size and can, therefore, process different articles. The principal design of the vertical CNC machines is presented in Figure 1.



Figure 1. Vertical CNC machine [10]

The machines include several essential parts, which are central to this project. These are presented below.

- *Capture unit*: A system to trap toxic gases generated during the processing of specific iron materials. Three machines have this system installed, two in U6 and one in U8.
- *Chuck*: A metal plate used to fixate rotation-symmetric components during the processing; see Figure 2. There are three chucks, two with a diameter of 900 mm and one of 600 mm.
- *Fixture*: A type of equipment used to fixate components of any geometry during the processing; see Figure 2.
- *Tool*: A term for various types of equipment used to perform processing activities. Examples of tools are drills, cutting tools, and mills.

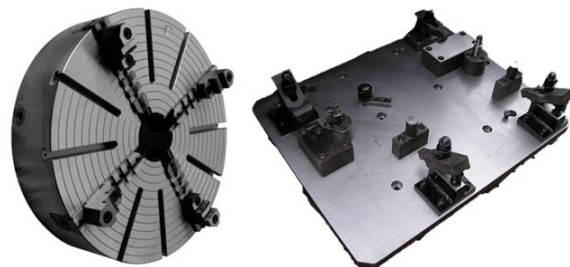


Figure 2. Chuck (left) [11] and fixture (right) [12]

The purpose of the empirical study was to collect and verify information concerning which factors had a significant impact on the available production capacity in West. The data collection was performed in three phases, videlicet unstructured interviews, semi-structured interviews, and archive analysis. The first set of interviews were carried out to get an overall understanding of the current situation and which factors to analyze closer. These were done with employees from various departments at Sandvik, to get a broad comprehension of the problem. Based on this information, semi-structured interview guides were developed and carried out with eight machine operators in West. During these conversations, deeper knowledge about the impacts of the potential constraints was obtained. The final phase consisted of a quantitative archive analysis of the discovered factors, which resulted in a completely objective analysis of the constraints.

The empirical study showed that the following three factors were potential constraints that could restrict the production capacity in terms of available equipment:

- *Capture unit:* 34 articles require this system, whereof 21 are machined in U6 and 13 are machined in U8.
- *Chuck:* 2 articles require the 600 mm chuck and 23 articles require one of the two 900 mm chucks.
- *Fixture:* 1 fixture is used by 7 articles, 2 fixtures are used by 4 articles, and 35 fixtures are used by 2 articles.

All the above-mentioned factors risk limiting the available production capacity, as the resources are fewer than the articles that require them during production. Thus, these constraints carry a risk of generating resource overlaps in the production schedule.

The empirical study also showed that many machine downtimes were caused by the tools, as the machine operators spent over 15 minutes on average when searching for them. This was, however, not a constraining factor from a production planning perspective, as the issue could not be avoided by an improved scheduling system.

Conclusions

The archive analysis showed that the identified constraints carry a risk of limiting the available production capacity in a situation where multiple articles demand the same resource at once. To understand if the constraints could satisfy the demand if accurately scheduled, further analysis of the forecasted production was done. This presented the total demand of all constraints, in hours, relative to their available utilization time. The analysis thus investigated the possibility of avoiding overlaps through proper scheduling. A negative result would indicate that investments to increase capacity might be necessary.

To quantify the results, a measure called Availability-Occupancy Ratio (AOR) was developed. This ratio presents the expected occupancy of a constraint as a percentage of the total available time during which it may be used. The results of the AOR calculations for all constraints are presented in Figure 3.

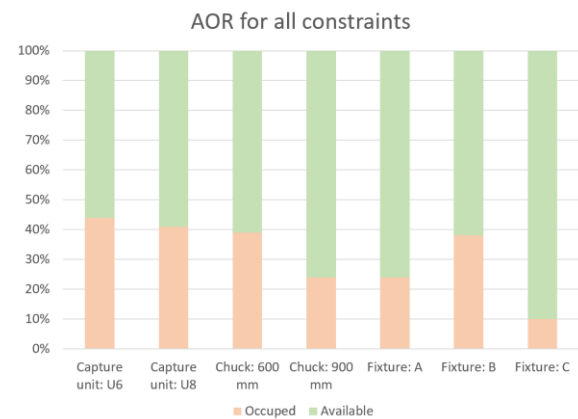


Figure 3. AOR for all identified constraints

The AORs shown in Figure 3 declare that none of the identified constraints is expected to be occupied more than 50 % of its available utilization time. In other words, if the scheduling is done according to these factors, it will be possible to avoid overlaps while maintaining enough capacity to produce forecasted orders. This result also establishes that there is no need to perform further investment analyses to increase the capacity of any constraint.

Based on the results of this project, it is recommended that Sandvik considers the three following factors as constraints in their new scheduling tool:

- Articles that require a capture unit
- Articles that require a chuck
- Articles that share fixture with other articles

Further, it is recommended that the company assigns a new project group to analyze the reasons for the long machine downtimes caused by searching for tools.

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