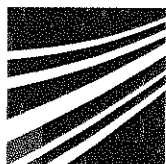


Sihn/Kuhlang [Ed.]

# **Sustainable Production and Logistics in Global Networks**

43<sup>rd</sup> CIRP International Conference  
on Manufacturing Systems  
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**Proceedings**



**Fraunhofer**



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# PROCEEDINGS

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## Development of a “convergent” order control for small and medium-sized production companies in the context of a turbulent market environment

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### Abstract

The paper explains the development and validation of a lean order control concept in the context of a turbulent market environment. Special emphasis is put on handling of an increasing number of variants, decreasing lot sizes and high demand fluctuation at the same time. The concept has been validated by an implementation in a medium-sized manufacturer of precision part in small and medium-sized batches.

### Keywords:

Factory and production planning, adaptive manufacturing

## 1 INTRODUCTION

Companies operating in a high variety/low volume, build-to-order manufacturing environment are particularly affected by market turbulences [1][2]. In comparison to series production, these companies work under much higher labor utilization. Scheduling and controlling within production is being complicated through discrete incoming orders as well as fluctuating sales figures of variants together with ongoing adjustments of the product mix [3]. Customers tighten their supply chain as well as their inventory management. Demand for shorter delivery periods rises. Over capacity within production causes permanent pressure to reduce replenishment costs.

Especially for SMEs, practice shows that the resulting planning dilemma can seldom be solved satisfyingly [4]. This is due to the high complexity of the problem, limited problem-solving skills on planning levels and lacking financial power. Thus, in order to establish a stable and practicable solution, besides an appropriate scheduling approach, a methodology has to be formulated simplifying implementation and operation.

The methodology, explained in the following, aims at SMEs' needs and is built up on two main approaches:

- Widening of the optimal operating point towards a defined operating interval



- Realization and settlement of the developed methodology via a strong organizational component within operation.

## 2 CHARACTERISTICS OF COMMON ORDER CONTROL CONCEPTS

Existing scheduling and controlling systems are based on concepts which are aligned with constant company growth. They are structured to handle different scenarios under full load and a maximum of machine availability. Production orders are planned under limited production capacity. Therefore, needed and available capacities are compared. So, feasibility and timely execution of orders are evaluated.

In case of insufficient production capacity, there is the possibility to adjust capacity in the future via for example extra shifts, outsourcing, etc. In practice, an increase in internal capacities is mostly preferred to outsourcing due to the threats of a necessary, active supplier management: If external manufacturing processes are integrated into the internal ones, the proportion of idle time typically increases, along with coordination uncertainty and effort.

Once the workload decreases, this factual over-capacity within production needs to be reduced. In order to adjust costs to revenue development, additional costs through extra shifts, energy and other resources have to be minimized. However, companies not seldom face several hindrances for a contemporary adjustment, e.g.:

- Insistent centering of economies-of-scale via pursuing high machine and worker load factor by planning and management staff
- Limited flexibility of workers/work contracts regarding adaptive working time models
- Constricted qualification profiles of shopfloor workers (e.g. a bottleneck machine can only be operated through one specific worker) [5]
- Limitation of flexibility of utilized planning systems: many ERP and production planning systems can only handle day-specific adjustment of capacity with large effort and many systems do not foresee a temporary adaptation of capacity in the forefront.
- Missing overview over key figures regarding the need of specific worker capacity per machine: how high is the necessary set-up time per shift and resulting from this which level of qualification is necessary at which time [6]
- The leading planning and control system as well as production data acquisition are not able to handle different processing status due to missing real time data. These differences in data quality might lead to redundant planning cycles and wrong allocation of machines.

Under these circumstances, it can easily be understood that a reduction of working hours, as the obvious measure to reduce over-capacity, may lead to significant gaps in machine and worker availability as well as, in succession, to longer production cycles.

Consequences are for example:

- decrease in supply availability;

- recessive adherence to delivery dates;
- high costs due to overhead rates resulting from over-capacity in direct and indirect areas.

In summary: A reduction of working hours leads to increasing cycle times which in turn leads to a decrease in adherence of delivery dates and even further decreasing sales.

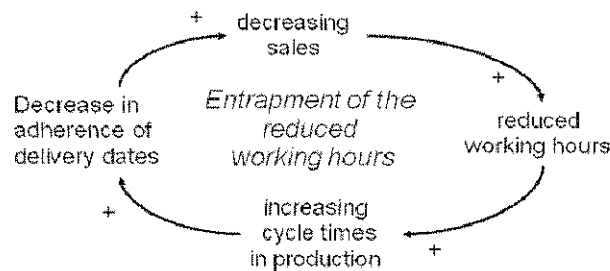


Figure 1: entrapment of the reduced working hours.

### 3 DEVELOPMENTN OF A "CONVERGENT" ORDER CONTROL

Any turbulent of sales situation, which could especially be observed over the last months, reveals the deficiencies of common scheduling and planning solutions. Instead of relying on specific software systems operating on complex optimization algorithms, comprehensive methods accompanied by adequate organizational concepts have to be utilized. In order to cope with the challenges described above, the planning tasks have to be structured hierarchically and organizational as well as technical measures need to be derived, thereupon.

For the developed methodology, the theory of an exact optimal operating point was abandoned. In fact, planning and scheduling tasks were defined enabling the determination of and compliance with an optimal operating interval. On the basis of an analysis of causal dependencies within planning and production plus analysis of disturbance variables and parameters, the methodology was designed to rely on a strong organizational component in order to assure converging capacity demand and availability profiles for given load scenarios. As practical consequence, the production portfolio was shifted from an exact-to-the-minute mixture towards week lots; whereupon main assumption has been to produce customer orders quickly and efficiently under complex manufacturing structures.

Delivery reliability, short replenishment lead time and decrease of costs can be characterized as USPs of SME companies operating at small and medium-sized batch production levels. For planning and scheduling tasks the following targets have to be prioritized:

- ensuring 100% delivery reliability;
- reduction of stock for finished goods by build-to-order;

- decrease in primary costs.

Conditionally upon the retention of an optimal operating interval, the optimization of productivity in regard to high machine load utilization is only embraced as a secondary goal.

In order to cope with turbulent order profiles and to ensure applicability under an aggravated implementation situation, that is mostly found within SMEs, the planning and scheduling methodology has to be backed up by adequate production and order management processes. For the configuration of relevant processes the following principles have to be met:

1. Anticipating and avoiding turbulences:
  - Possible disturbances need to be avoided in the forefront through planning and organizational methods.
  - Order clearance is only given if all necessary material and tools are assured.
  - The size of orders for long running articles is reduced in order to cut cycle time. Smaller orders are not constrained any longer.
  - Manufacturing orders are only given clearance if they are actually being processed in production in order to reduce cancellations and rescheduling of orders to a minimum. [7]
2. Optimized build-to-order:
  - In order to reduce capital commitment stocks for finished goods in general as well as especially of series parts should be reduced to zero.
  - The value chain is being separated into pre-production and final production in order to comply with the customer's delivery time.
  - The inventory of pre-produced/semi-finished parts is being managed according to the pull-principle.
  - Higher-risk manufacturing processes are also integrated into pre-production in order to minimize scrap in the final production.
3. Continuous production and procurement:
  - idle time and queuing should be significantly reduced via continuous flow orientation and strictly maintaining the FIFO-principle at machine level.
  - Bringing forward and rescheduling of orders to merge changeover time should be avoided. This can be realized by transferring order data in time restricted shifts only (e.g. daily). [8]
  - Integration of supplier processes into production planning with the help of computer aided information technology enables timely handling and controlling of the external order processing. Suppliers are being provided with forecast data over a web-client in real time.
4. Takt-production principle
  - The delivery date of a production order is based on the calculation of standardized, modularized lead times.
  - Machine utilization is initially based on a maximum of two shifts in order to ensure maximum flexibility.

- The promised delivery date must be adhered to. Keeping the takt is mandatory. Peak loads due to parallel manufacturing tasks are offset by vertical and horizontal expansion of capacity (increase in shift hours and additional working days).
  - The creation of work packages for each work center in the form of daily workloads (i.e. the daily takt) with defined start and end dates ensures constant work progress.
5. Flexible capacity
- Qualification of staff members (by job rotation) ensures that there are no "know-how-bottlenecks".[9]
  - Shift and working time patterns indicating minimum and maximum attendance times, working time account, and a defined "frozen zone" enable adapted and flexible capacity utilization.
  - Within the "frozen zone", machine and staff capacity are planned exact to the day and for each work center.
6. Creating transparency
- Uniform, transparent rules for the planning and control processes are defined.
  - The detailed operation sequencing for each day is planned on the shop floor by foremen and/or employees.[10]
7. Measuring success
- The performance measurement system is used to measure how successful and efficient the planning activities were.
  - The level of goal achievement is part of the bonus scheme.

The solution approaches and design principles were integrated into a specific order control software tool meeting the needs of SMEs. Context-dependent restrictions are limited financial and human resources, highly flexible resources as well as reliable process control in order fulfillment.

### **3.1 Step 1: Reduction of complexity via standardization**

Mainly, the calculation of delivery dates is based on resource utilization, shift patterns and order volume. This, for example, results in diverging delivery dates for repetitive orders. A solution is to calculate realistic lead times in a standardized and repeatable way via a sequence of adequate lead time modules. Therefore, the modularized total lead time of an order is based on key figures/performance measures. It is independent of utilization and customers, but takes the delivery route and procurement criteria for tools, services and materials into account.

The standardized lead time can be evaluated in a reliable and repeatable way through the order specification and with the help of the sequence of technologies. This covers the planning forecast, material procurement, internal cycle times, external idle time as well as the shipping time.

The standardized lead time defines the latest starting point for production on the basis of the desired delivery date. The customer receives a delivery date as early as possible as an instrument of prognosis in the context of the delivery date prognosis.

If the delivery date calculated on the basis of the standardized lead time exceeds the customer requested delivery date, the tool helps to determine the transition from pre-production to final processing stage.

The method was underpinned in a standalone IT-tool for planning and control tasks. Release rules and exemptions are defined and are considered and supported in IT systems.

### **3.2 Step 2: Demand-driven order scheduling**

The described methodology and PPC tool were designed to fit the needs of commonly equipped companies. Correspondingly, the delivery dates calculated on the basis of the standardized lead time modules have to be entered into a superior (ERP) system enabling data transfer from and towards production data collection system (PDC) as well as tool administration system (TAS) in real time. The necessary information for monitoring the order status is integrated in the PPC tool from various facilities.

The superior ERP system has to provide shop calendar, standard shift pattern, production orders, delivery dates, order status, stocks, technical availability or work centers and group assignment. For every article, the TAS has to provide the necessary tool BOMs or fixture BOMs and their availability status for each operation. The PDC has to inform about the processing status of each operation.

Operations planning – as owner of procurement processes from supplier and to the customer – releases production orders only after two checks have been made. One is the availability check for materials and tools and the other is the time check, which examines, if the distance to the latest possible start date has fallen below a defined value. Manufacturing control checks first, if the standardized lead time is shorter than the available lead time. If not, the delivery date must be postponed or can only be processed, if additional capacity is used (horizontal expansion: Saturday, Sunday). All released production orders are scheduled according to the FIFO-principle.

The PPC tool schedules backwards, starting with the delivery date according to the principle of the latest possible start date for all operations of a production order. Starting point is the last operation. If the necessary capacity at the next possible date is available, this capacity is reserved for the operation according to the FIFO principle. If only some of the necessary capacity is available, then the required capacity is split and scheduled for the preceding day. If no capacity is available to the next possible date, then it is attempted to schedule at preceding days, etc. If due to the lack of capacity the start date of the first operation of the production order lies in the past, then the production order becomes a bottleneck order. The PPC tool will calculate for each operation, how many days there are between planned and actual start date as well as visualize it in three colored states (planned = actual; up to 2 days of difference; more than 2 days of difference). Manufacturing control can thus immediately see which work station represents a bottleneck. The PPC tool allows adapting the shift pattern to the bottleneck resource by additional full or half-time shifts according to need. So, capacity adjustment becomes visible and the start date of the

production order will be adapted. This procedure can be repeated for all operations of the production order until the start date lies in the future.

The process of capacity adjustment only takes into account technical capacity. At the same time, manufacturing control must permanently verify capacity adjustment against staff availability and qualification level. The basis is provided by the information compiled in the PPC tool. For each day, the planned times per unit for every machine/work center are added and the required change over times indicated separately.

### **3.3 Step 3: Workplace-specific availability**

Regarding the process of resource allocation using the PPC tool, the workplace-specific availability is of high importance. Frequently, downtime and maintenance times are subtracted globally on the basis of conveyed knowledge. In addition, change over time is generally defined for each operation deploying past values. These assumptions, experientially, result in an error in the significant range.

Machine availability has to be analyzed together with the availability of personnel. Especially concerning multiple-machine operation the calculation of capacity demand and compensation with available machine- and workplace-specific personnel capacities is necessary. Therefore, worker profiles have to be described workplace-specifically, actualized continuously and taken into account for order fine-planning. Available capacity on workplace level can be increased significantly by cross-assignment of workers enabled by qualification via for example job-rotation. Thus, market turbulences like shifts within the variant mix and lot size deviation can easier be compensated internally and bottlenecks can be avoided.

In a high variety/low volume or build-to-order manufacturing environment a lot of change over is executed. The setup expenses and the associated change over times often deviate strongly. Some reasons are:

- the course of incoming orders is discrete, machine scheduling is driven by events and actions on the shop-floor are situational;
- sparse standardization and hereby long change over times, unplanned downtimes, missing components;
- change over times for the part-sequence A to B is different from the part sequence B to A.

Several approaches for planning try to calculate the efforts for change over caused by the operations by means of changeover matrices. The basic problem is the determination of the operations during detailed planning. Small faults regarding downtimes can result in extensive date collisions in the overall system due to the bullwhip-effect.

Along the value chain processing steps often possess a very different degree of standardization depending on the different companies and the respective technologies. Operations, which are related to the core competences, normally exhibit a higher diversification concerning tools and devices and therefore a higher percentage of change over. Within the scope of the developed methodology/tool the aim is to modularize the downtime. The downtime modules are built for each workplace separately depending on the input of the different functional units. Changes in downtime mod-

ules are controlled and continuously adapted by means of the PDC. Included data are:

- planned maintenance;
- disruptions and breakdowns;
- downtime due to change over.

This approach approves using exclusively verified part times in the planning process. Nevertheless additional demands of capacity could occur. Those will be covered by flexible working hours.

#### 4 IMPLEMENTATION PROJECT

Methodology and tool described above have been validated within an industry project. The industry partner manufactures drive components for a large number of mechanical engineering and plant construction companies. These parts require long operation times due to complex heat treatment and chip-cutting operations. The order portfolio consists of small batch series and a large number of single orders. The scope of order is characterized through increasing variances and decreasing lot sizes. Series production was manufactured into stocks. Insufficiencies within manufacturing and missed deadlines were compensated at the expense of capacity and were not made transparent. The drastic decrease in sales, leading to a minatory reduction in liquidity, forced the company to induce a significant change.

For validation, the PPC tool had to be adjusted to the specific requirement framework of the company's IT landscape as well as adjustments in process map and organization had to be made. Methodology and tool have proven their worth: Within a manageable amount of time the production situation could be stabilized and the capacity situation adapted to "real" needs. Demanding worker flexibility, dependable purchasing processes as well as ingenuity and precision in planning and execution, the validation project helped to identify crucial deficiencies for further growth after the crisis situation.

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