Production Management A

- Lecture 7 -
Operations Control

Learning target of this lecture:
• Overview of tasks and objectives of operations control
• Understanding of the challenges in real life
• Understanding of the principles and processes of operations control
• Knowledge of applicable methods
Short content of the lecture

- Introduction of the tasks of operations control (p. 3)
  - Tasks and objectives of operations control will be defined and classified in the context of production planning and control (PPC).

- Challenges of operations control (p. 7)
  - The basic challenges of operations control will be specified and clarified with case studies.

- Methods and strategies of operations control (p. 11)
  - In the main part methods and strategies of operations control will be introduced.
    - Focus:
      - Push and pull order release (p. 12)
      - Flow scheduling (p. 16)
      - Capacity balancing and capacity smoothing (p. 18)
      - Load-dependent order release (BOA) (p. 23)
      - Priority rules for order release (p. 24)
      - Kanban (p. 25)
      - Dimension of time in operations control (p. 28)
Definition of Operations Management

Operations management:
Operations management includes the arrangement for, the monitoring and guaranteeing of quantity, deadline, quality, and cost

Tasks
- Arrangement
  - Creation of programme and order
  - Determination of demand
  - Determination of deadline
  - Staging and task distribution
- Monitoring
  - Quantity and deadline
  - Quality
  - Budget accounting
  - Working conditions
- Guaranteeing
  - Intervention and modification to planning
  - Quality management

Objectives
Costs Minimization by Optimization of Production-Economical Objectives
- High Due-Date Reliability
- Short Lead Times
- High Capacity Utilization
- Low Shelf Inventories and Float Floor Stocks
- High Service Level
- High Flexibility
- Constant Capacity Load
- High Level of Information
- ...

Picture notes:
Introduction

Challenges

Methods and Strategies

Tasks of Operations Management: The Aachen PPC-Model

**Network Tasks**
- Network configuration
- Network marketing
- Network requirement planning

**Core tasks**
- Production program planning
- Production requirements planning
- Procurement planning and control
- In-plant production planning and control

**Cross-sectional tasks**
- Order coordination
- Inventory Management
- PPC-Controlling

Data management

(source: Schuh 2006)

**Picture notes:**

The function of the Production Planning and Control (PPC) is the time, capacity and quantitative planning and scheduling of the production and assembly (Eversheim 1989). Whereas the production planning has to organize the content and the single processes of the production and assembly, production control has to organize the operations in the production within the scope of order processing. The production control takes input from the production planning regarding the process sequence and associated logistics objectives.

The focus is on the company internal planning and control processes. Due to diverse customer demand, globalisation of procurement, sales markets, substitution of goods and the increasing process of globalisation, companies are under immense pressure to strengthen and focus on value adding processes in the whole supply chain. To cater this growing integration in the supply chain, the Aachener PPS Model has introduced in the network to manage the dependence.

The tasks of production planning and control can be divided into core tasks and cross-sectional tasks. While core tasks advance the order processing, cross-sectional tasks aid to integrate and optimise the production planning and control.

Core tasks are long term production programme planning, medium term production requirement planning, short term in-plant production planning and control and short term procurement planning and control. Cross-sectional tasks are order coordination, storage and the controlling of the ERP system itself.
**ERP Workflow ("Aachener PPC-Modell")**

**Picture notes:**

During the planning process, resources are planned with increasing level of detail and decreasing planning horizon. The results of a planning step are input for the next step. Planning information is fed forward to the next planning step with the aid of a control loop. The core tasks of PPC can be shown in a flowchart.
Subdivision of functions of the PPC/ERP

Introduction
Challenges
Methods and Strategies

Production requirement planning
- Gross secondary requirement determination
- Net secondary requirement determination
- Allocation of kind of procurement
- Lead time scheduling
- Capacity requirement calculation
- Capacity adjustment

Operations planning

Production program planning
- Sales planning
- Primary requirement planning
- Resource planning

Materials management

Self-manufacturing planning and control
- Lot sizing
- Fine scheduling
- Detailed resource planning
- Sequence planning
- Disposability planning
- Order enabling

Procurement planning and control
- Order invoice
- Offer evaluation
- Vendor selection
- Subscription enabling

Operations Management includes methods which are necessary for the processing of orders according to the results of work scheduling. One factor that influences operations management is the kind of dissolution of orders. In addition, the tasks of operations management are influenced by products, procurement, workflows in manufacturing and assembly and by customer changing priorities during manufacturing.

Inspite of the different characteristics of the specific factors in different companies, core tasks and cross-sectional tasks of operations management can be identified in a universal concept. Core tasks are production programme planning, production requirements planning, in-plant production planning and control and procurement planning and control.
Multi-dilemma of operations control

Equal & high workload:
- High inventories
- Low capital
- High order capacity

High date of delivery loyalty:
- High inventories
- High stock of material
- Low workload

Lead time:
- Low stock of material
- High capacity
- Low workload

On-time delivery:
- Low capital commitment:
  - Low stock of material
  - Short lead time

Transfer to capital lockup

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Picture notes:

Two challenges must be taken into account within the multi-dilemma of operations control:

• Conformity between workload in production (by customer orders respectively market specific orders) and own capital commitment

• Adjustment of lead time of production orders with the scheduled delivery date. At this point, the waiting within the lead time and the delivery date should be considered
Co-Ordination Materials Management / Assembly Control

**Picture notes:**

Operations Control and Materials Management can not be separated in the handling process of production assignments. The coordination of the non-physical information flow with the associated physical flow of material is the core challenge of an effective production planning and scheduling.

A lack of coordination between materials management and production & assembly scheduling will result in a disturbance of the assembly even though high stock levels are available. These disturbances increase with an increase of variety and complexity of the products in combination with variation of demand.

In the graph is shown that 91% of production disturbances are caused by material problems, despite of the high inventory level (the stock suffices for 70% of the code numbers for more than 5 month). It is significant that 53% of the material conditional disturbances are due to missing parts. A better coordination between inventory management and assembly control can therefore reduce both the disturbance quota and inventory.
Planning Tasks and Levels of Operations Management

Picture notes:
Production control is taking charge of the results of the production program plan as well as production requirement planning. Manufacturing orders as well as primary and secondary needs are available and contributed during the first step of job processing control, lead time and capacity scheduling.

Graded planning is carried out on several levels in order to keep the large volume of data under control. For planning on higher levels, aggregated data is used; planning on higher levels has a longer planning horizon. In contrast, planning on lower levels is short-term planning, but uses detailed data.

Two basic planning problems arise. The "information gap" exists in early planning phases since enough information for a more intensive and therefore more detailed planning is not available yet. The "effectiveness gap" during the later fine planning expresses that detailed data for the planning is existing but the intervention possibilities are restricted due to the temporal closeness to the start of production.
Types and Framework of Orders for a Mechanical Engineering Company

**Introduction**

**Challenges**

- Customer order: 1,200 orders / yr.
- Assembly processes: 18,000 / yr.
- Assembly orders: 1.2 mio. / year
- In-house production parts: 1,000
- Outsourced parts: 2,500
- Yearly requirements: 3 mio. / year
- Assembly processes: 100
- Assembly types: 15
- Purchase order: 120,000 / year
- Machine types: 350

**Framework of orders for one machine:**

- **Parts production:**
  - In-house production parts: 1,000
  - Outsourced parts: 2,500
- **Assembly:**
  - Assembly orders: 15
  - Assembly processes: 100

*(source: Traub, 1991)*

**Picture notes:**

The difficulties of operations control are caused by a high number of different parts to be produced and obtained. A high number of orders which must be coordinated with regard to their completion appointments and capacity requirements results from it.

This problem is found particularly with complex products and customer-specific production. Normally there are so many operations necessary that even a mid-sized company needs the support of a PPC-system for its operations control.
Characteristics of Order Types for Production Control

**Order types**

<table>
<thead>
<tr>
<th>Customer-anonymous</th>
<th>Customer-specific</th>
<th>Mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Delivery ex stock</td>
<td>• Delivery after running through engineering, operations planning, production, and assembly</td>
<td>• Delivery determined by assembly time</td>
</tr>
<tr>
<td>• Customer-anonymous production and assembly of lots for stock</td>
<td>• Nearly no stock or lot production</td>
<td>• Production of basic components for stock, customer-specific production and assembly of variants</td>
</tr>
<tr>
<td>• No customer demands</td>
<td>• All customer demands</td>
<td>• Customer demands within the framework of combination</td>
</tr>
</tbody>
</table>

(source: Wiendahl)

**Picture notes:**
Based on the product and the present market situation, there are different types of solutions for an order. A producing company that needs to provide its goods on a continuous basis, will standardise its products and keep a high stock level. This results in a high level of capital costs. With an increasing customer orientation, the demand of time and capacity planning rises. The companies focus is to meet the delivery date on time.
**Principles and Characteristics of Push-Pull Control**

**Legend:**
- **Push**
- **Pull**

**Material procurement according to production programme**
- **Push**
- **Pull**

**Storing of components**
- **Push**
- **Pull**

**Storing of customer-independent products, sale ex stock**
- **Push**
- **Pull**

**Sale of customer-specific products**
- **Push**
- **Pull**

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**Picture notes:**

The application of various methods depends on the product and/or order structure.

The different types of order triggering require different mechanisms of operations control. One distinguishes basically in Pull and Push control (Wiendahl):

1. **Pull control (Pull)**
   - **Aim:** Guarantee of the availability of a certain quantity within one period of time
   - **Features:**
     - Order release triggered by a customer demand in direction of the material flow
     - Orders without closing date and job number
     - Synchronization of input and output

2. **Push control (Push)**
   - **Aim:** Focus on completion on schedule
   - **Features:**
     - Order release triggered by a superior planning level
     - Orders with closing date as well as job number
     - No synchronization of input and output

The limits of Pull and Push control circles have to be established specifically for every enterprise in dependence of capital relationship and desired delivery time. The structuring of products into assemblies and components without variant influence (neutral assemblies) supports the specification of these limits. Superordinated planning functions for long and short term planning are frequently affected by the push-principle and with approaching the start of production they are supplemented with control systems based on the pull principle.
Effects of Push Control

Picture notes:
The application of the Push control principle means that a high inventory is necessary to make a custom-designed final assembly possible. This inventory grows with the increase of the diversity of variants since all variants must be on stock to meet the customer requirements.

Since the planned inventory depends strongly on the quality of the forecast of the customer demand, an overestimation of the demand causes a very high inventory level. If the forecast values are below the actual demand, a low inventory leads to low material availability. Therefore the choice of the right forecasting method for the respective products is of great importance (compare PMA L8 “Material management”).
Expansion of Pull-Controlled Production Volume (Example)

**Picture notes:**
A synchronised assembly increases the planning flexibility in production and results in lower stock levels in the assembly area. It is useful to implement this measure if the assembly requires time and if high part value and/or part volume is involved.

For example: airplane production: Supply of jet engines as late as possible

The assemblies and components which are necessary for the assembly are divided up into stock classes. They are manufactured (push controlled) without any direct relation to a customer order but according to their different use frequency. The corresponding variants are produced custom-designed (pull controlled) in the assembly from the stored assemblies and parts. The pull controlled assembly makes a lower inventory possible since only assemblies and parts must be stored.

The interface between pull and push control is called order penetration point.
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Tasks of the production requirement planning

The input information for the production requirement planning is the production plan. The production plan is the result of the production program planning. For a certain planning horizon for example a year the monthly lot size of the products or product parts are listed (planning pattern). The task of the production requirement planning is to secure the production program with adequate procurement programs. The considered resources (production factors) are production facilities, material (secondary demand), personal, transportation devices etc. that means everything that a production process incorporates.

Secondary demand planning calculates the actually needed amount of raw materials, parts and groups and matches them with the appropriate procurement type (in house production/outside supply). Finally the classical tasks of time management (lead time scheduling and medium range capacity planning) occur. These are the basic tasks of operations control and are the basis for the short term planning of in house production.
Order- and capacity-based scheduling

**Phase 1**
(Focus: work-piece)

Order-based scheduling

- Deadline plan
  - Order 1: 1.1, 1.2, 1.3

**Phase 2**
(Focus: machine)

Capacity-based scheduling

- Deadline plan
  - Order 1: 1.1, 1.2, 1.3
  - Order 2: 2.2, 2.3
  - Order 3: 3.1, 3.2, 3.3

**Deadline overview**

- Lead time for order 1
  - Work systems: A, B, C
  - A: 1.1
  - B: 1.2
  - C: 1.3

- Lead time for order 1
  - A: 1.1, 3.1
  - B: 2.2, 1.2, 3.2
  - C: 2.3, 1.3, 3.3

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**Picture notes:**

When setting the dates for customer-oriented production, the start and completion dates for each step (operation) must be determined with the due date in mind. Various types and methods of date-setting are used.

Within **order-oriented** scheduling, only the data relating to one order is taken into account. The basic scheduling methods (e.g. forward and back-ward scheduling)

Within **capacity-oriented** scheduling, the mutual dependency between orders and therefore between capacity limits is considered.

As a rule, at first order-oriented then capacity-oriented scheduling is conducted.

The results of lead time scheduling within production requirement planning are basic dates related to capacities respectively capacity groups. Later the actual state of charge can be taken into account (Wiendahl 1989).
Scheduling

**Backward Scheduling**
- Starting point is a fixed final date (e.g., desired delivery date of the customer)
- Calculation of the latest possible start date backwards from the final date
- If the calculated date is situated in the past, methods will be applied to reduce the lead time

**Forward Scheduling**
- Starting point is a fixed start date
- Calculation of the earliest possible final date forward from the start date
- Problem: material will be ordered too early
  - Forward scheduling is only applied to calculate the earliest possible delivery date, afterwards the latest start dates (and therefore order dates) are calculated with help of backward scheduling

**Combined Scheduling**
- Starting point is a fixed centre date
- Calculation of the latest possible start date and the earliest possible final date
- If the calculated date is situated in the past, methods will be applied to reduce the lead time
- Application is useful, if the bottleneck capacities have to be taken into special account

### Distribution of Schedule Deviations

- **Legend:**
  - Setup Time
  - Operation Time
  - Transitional Period

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**Picture notes:**

The (period based) supply orders and particularly the in-house production are planned in the lead time scheduling. Therefore each process step has a fixed date according to the production sequence. The lead time is comprised of the processing time (start up time and operation time) and the waiting time (standby time before and after the processing, control time and transport time). Depending on the planning method limited or unlimited capacities are taken into account for the scheduling. The latter one means that the constraints of available capacities are not yet considered. The planning basis for these tasks are work schedules and transfer matrices. In a transfer matrix planned values of the inter operation time for each transfer from one workstation to another workstation are listed. It can be differentiated between three different types of scheduling:

- **Forward scheduling:** The earliest due date is calculated based on a fixed start date
- **Backward scheduling:** The latest start date is calculated to fulfill the contract on time based on a fixed due date
- **Combined scheduling:** Based on a fixed starting point a forward scheduling into the future and a backward scheduling into the past is done. It is possible to start with any particular process when using the combined scheduling. For this process a fixed date can be planned. This method can be used if additional considerations such as bottleneck machine havens have to be taken into account.
**Time- and machine-based harmonisation of capacity**

**Picture notes:**
Within capacity planning, the distribution of activities among the individual units of capacity is optimised, under consideration of the load limitations. **Capacity harmonisation** and **capacity adjustment** are possible measures.

A further distinction is made between **technical** (e.g. parallel dispatching of an order on another machine) and **time-based** capacity harmonisation (e.g. the same machine, but later dispatching).

In industrial practice, time-based and technical capacity harmonisation operations are usually combined. Normally, the time-based harmonisation is first, in order to retain optimum use of capacity in terms of both engineering and cost. Placing an order with an external company (extended work-bench principle) is a further option.
**Introduction**

**Challenges**

**Methods & Strategies**

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**Handling time / Transitional period / Control period**

Handling time and control time mark constant values. Handling time is added before the start-up of a process operation, control time is added after the ending of an operation. Both factors do not occupy any capacity but they heighten the machining time.

The transitional period indicates a time exposure that arises from product transport within manufacturing from one workplace to another or from an effort conditional on production after a process operation (e.g. cooling, drying etc.).

**Split factor (cut within production)**

If the temporal effort of production for one process operation cannot take place on a single work day because of lack of capacity or duration of the production, time has to be spread on one or several days. If such a splitting is not possible or only in parts because of production reasons, the splitting can be managed by depositing the split factor within the process operation.

**Capacity factor**

Usually, the basic capacity of a workplace is deposited within the machine group with 100% of the available time. This available capacity can be reduced because of external factors such as machine's cooling times, breakdown time, frequency, and maintenance. Therefore, additional capacity reserves for critical situations can be created.

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Measures for adapting the capacity

**Internal/ external alternative capacity**

**Overtime/ short-time working**

**Additional shift**

**Investment**

**Internal influencing factors**
- effectiveness
- duration
- internal priority

**External influencing factors**
- external priority
- penalty
- labour market
- economic situation

**Selection and execution of measures geared to adapting to capacity**

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**Picture notes:**
When the company-specific parameters change, e.g. expansion, acquisition of a new major customer etc., the capacity harmonisation measures are generally not enough and it becomes necessary to adapt capacity to the changed parameters.
Tasks of In-House Production Planning and Control

**Picture notes:**

The planning result of the manufacturing orders based on the production requirement planning assures that the resources are available. The planned orders contain operations that are executed in different manufacturing sectors. Through finite resource planning the availability of the needed capacities can be secured. Capacity planning relies heavily on material management to provide the raw materials as planned in production.

The internal production planning and scheduling particularises the guidelines of the available material planning tolerance and the conversion is controlled. Manufacturing orders can be split into different lots. The calculation of the optional lot size is another task of the operations control (see PMA L8). The material planning tolerance is the difference between earliest and latest start date of the production and the allocation of the quantities to the manufacturing orders.

At the end of this planning the key task is to assign manufacturing orders to machines. The final order release can occur in a variety of possible algorithms.
### Comparison of order release strategies

<table>
<thead>
<tr>
<th>Principle</th>
<th>Pull control principle</th>
<th>Push control principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>• Progress rate system (FZS)</td>
<td>• Material Requirement Planning (MRP I) • Management Resource Planning (MRP II) • Optimized Production Technology (OPT)</td>
</tr>
<tr>
<td>Inventory</td>
<td>• KANBAN • Load-dependent order release (BOA)</td>
<td></td>
</tr>
</tbody>
</table>

**Picture notes:**
Different control strategies can be compared on the basis of control principle during the materials allocation on one hand and the control parameters on the other hand. Detailing of different release strategies will be discussed to a large extent in production management II.
Load-dependent order release (BOA)

Picture notes:
Load-dependent order release ("Belastungsorientierte Auftragsfreigabe", BOA) is a stochastic method. The controlling factor of this period-oriented method is the backlog in front of work stations, which is continuously calculated. Only those orders which have to be finished within a defined deadline are considered part of the urgent backlog. When an order is part of the urgent backlog, it will be checked if its load dues fit within a defined load limit.

Indirect load dues will be considered with a reduced load due according to their reduced arrival probability and their reduced load. If there is no capacity for any production step, the whole order will be retained.

The advantage of the BOA method is the high flexibility in case of varying order numbers. However, there are problems in controlling orders that consist of many steps.
Use of Priority Rules for Sequence Planning

<table>
<thead>
<tr>
<th>Priority rules</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCFS</td>
<td>First come, first served</td>
</tr>
<tr>
<td>SPT</td>
<td>Shortest processing time</td>
</tr>
<tr>
<td>RAN</td>
<td>Random number per operation</td>
</tr>
<tr>
<td>RAND</td>
<td>Random number per order</td>
</tr>
<tr>
<td>SROT</td>
<td>Shortest remaining operation time</td>
</tr>
<tr>
<td>TERM</td>
<td>Finish date</td>
</tr>
<tr>
<td>SLACK</td>
<td>Slack time</td>
</tr>
<tr>
<td>LPT</td>
<td>Longest processing time</td>
</tr>
<tr>
<td>OP/RE</td>
<td>Operation time / remaining machining time</td>
</tr>
<tr>
<td>STRUN</td>
<td>Shortest processing time with limitation of waiting time</td>
</tr>
<tr>
<td>S-SL</td>
<td>SPT if slack time sufficient, otherwise SLACK</td>
</tr>
</tbody>
</table>

Picture notes:
Queues arise from the allocation of orders to the individual jobs/machines. The order of the orders to be worked on can be defined with the help of priority rules if the fine planning of the workshop doesn't find any exact specifications. The priority rules should be selected according to the aim.
Use of the pull principle: kanban method

Kanban is a production control method using the pull control principle that makes permanent intrusions of a central control unit unnecessary. It is solely oriented at the customer demand.

**Definition Kanban:**

Kanban is a production control method using the pull control principle that makes permanent intrusions of a central control unit unnecessary. It is solely oriented at the customer demand.

**Picture notes:**

**Description:**
The Kanban method is based on decentralized, self-controlled loops. It is characterized by the following aspects:

- Production starts as a reaction to a requirement notice from the next production level.
- Flexible use of production facilities and personal balances fluctuation of requirement rate.
- Buffer storage between production levels.
- Kanban cards as information device between communicating sites.

**Use:**
Introduced by Toyota the Kanban principle is used for the communication between different production levels in operations control. For example the supply of an assembly line with small parts or self produced components can be accomplished without the central PPC system.
Picture notes:

1. To obtain the needed parts for the production, a worker from the drain moves with the empty containers to the buffer storage of the control circuit. He will place the empty containers in their intended places.

2. He takes the needed amount of full containers out of the buffer storage.

3. After the removal of the attached Kanban he places the Kanban Card in the Kanban collecting box.

4. Then he moves with the full containers to his workplace and starts production.

5. A worker of the source takes a Kanban out of the Kanban collecting box. This Kanban is a production order for the source.

6. The worker of the source retrieves the container that is listed on the Kanban out of the buffer storage and moves to his workplace where he starts producing the needed parts.

7. The finished parts will be put in the empty container. Then he attaches a Kanban to the full container and delivers the container to the buffer storage where he places the container on the intended place that is mentioned on the Kanban.
Advantages and disadvantages of kanban

**Advantages**
- Small amount of stocks
- High service level and punctuality
- Reduction of lead time
- High transparency of flow of material
- Low control costs
- Low data management and production data collecting costs
- Higher responsibility of the employees
- Low stocks result in an accurateness of the employees

**Disadvantages**
- A small amount of buffer stock leads to a break in production of the following levels if a disruption occurs.
- Highly fluctuating amounts are not controllable
- Small multiplicity of variants/high amount of constant components

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**Picture notes:**
Composition of Throughput Time

- Throughput time: 100%
  - Machining time (including setting-up): 10%
  - Transport time: 2%
  - Control time: 3%
  - Queuing time: 85%

  - Queuing time caused by work process: 75%
  - Storing time: 5%
  - Queuing time caused by interruptions: 3%
  - Queuing time caused by persons: 2%

Picture notes:
Analyzing preferably job shop production organized manufacturing sectors shows, that the main part of lead times is not participate in productive progress. A big rationalization potential is lying in control of procedures by reducing high queuing times.
**Picture notes:**

In the case of lot manufacturing, the actual proportion of unproductive time within the throughput time rises with increasing lot-size. In addition to the transition times between two operations, lot-size related waiting times within an operation can also be reduced.

On the one hand a large lot size causes a short changeover time, but on the other hand all work pieces have to wait on each other. The determination of optimal lot size is not trivial.

See also PMA L8: Determination of the optimal lot size
Methods of Reducing Production Throughput Time

**Picture notes:**
There are different possibilities of reducing the transmission delay of an order. When splitting operations e.g. a work step can be carried out at the same time on two machines instead of only one machine. Another method is overlapping the production, this means the next work step doesn't start after the completion of the whole lot but after the completion of just a part. Furthermore the setting up of operations with the same set-up process can be joined together for saving make-ready times so that parts of the order A are produced together with parts of the order B.

The allocation of orders to the individual workplaces results in queues. The sequence in which the orders are to be processed can be determined using priority rules in case the detailed shop-floor plans do not contain any exact specifications. Rules are selected depending on the objective.
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