Contents

1. PLANNING, CONTROL AND COMMUNICATION SYSTEMS

1.1 Process structures as structure and outline of the process items

1.1.1 Parties involved in the process (Workflow Management)

Here the operational process structures are considered, in particular in relation to the different levels of a business or company.If one divides the process related to production areas and the department formation, the following structures can be seen:

- Development and Construction
- Work Preparation
- Procurement
- Production Control
- Manufacturing and
- Quality Control
- Components Manufacturing
- Assembly
- Shipping

1.1.2 Process structures in the manufacturing process

The relationships, links, dependencies also in terms of the reciprocal influences between the process elements are represented by the description of process structures.

This outline shows the possible process structures:

1.1.2.1 Manufacturing principles

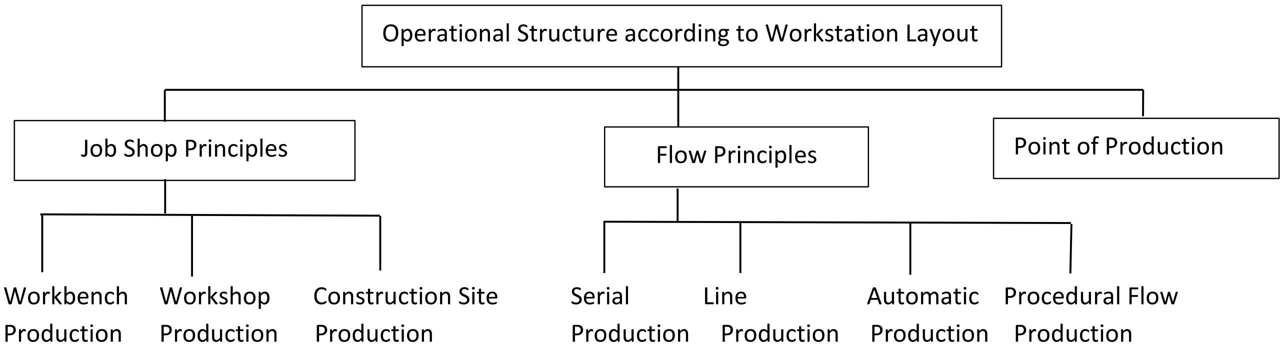


Figure. 1: Manufacturing Principles

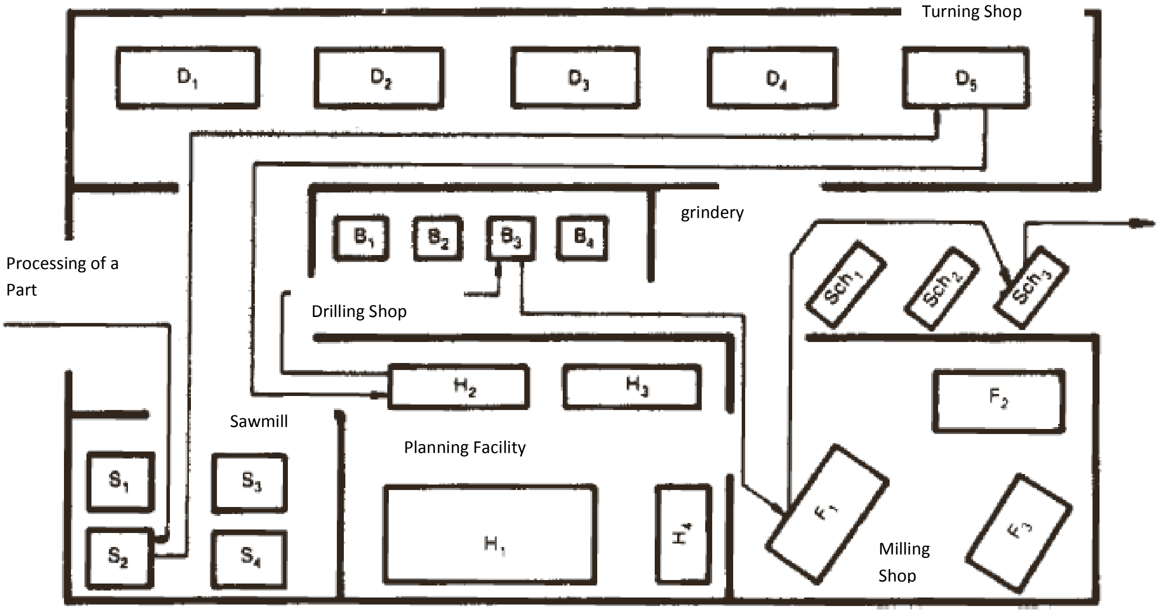


Figure 2: Workshop Production

With the job shop principle, similar tasks are performed on similar types of jobs and operating equipment

a) Bench Production

The workbench production is a localized job on which the products either individually or in small quantities are produced from the beginning until the end of the processing. It is found mainly in the trade sector and distinguishes itself partly through a low degree of mechanization level. The profitability of this type of production is low. The qualification of the workers is high – usually skilled workers.

b) Workshop Production

In the workshop production similar operations are performed on similar types of jobs and operating equipment which are spatially grouped to departments (such as, all lathes in the turning shop, milling machines in the saw mill). The components migrate, depending on the processing sequence, from workshop to workshop.

Despite significant disadvantages, which the workshop production brings with it, it is still the most widely used in mechanical engineering. This is due to the fact that the prerequisites of the flow principles are still missing. The range of parts are usually very extensive, the size of the series low and the production program not stable over long periods of time.

c) Construction Site Production

You can apply this flow principle for example in the pressure pipeline construction, in large installations of spherical tanks and in maintenance work, etc.

Advantages of Job Shop Principles:

- high production flexibility, i.e. low sensitivity of the operation against order fluctuations on type and quantity
- resistance to fluctuations in employment (e.g. due to illness, absence of personnel, repair of machinery, congestion in the supply of material, etc.)
- good adaptation to the changing needs
- high utilization of time and resources
- therefore, lower capital commitment of resources
- production program changes are possible without too much planning and preparation.
- the professional qualification of the master is confined mainly to the respective procedure (the master turner is only responsible for the turning shop, the milling master only for the milling shop)
- in contrast to the assembly line work, less waiting time of workers because every workplace is relatively independent of the preceding jobs.
- the space of work can be tailored to the individual worker's performance, disposition and motivation

Disadvantages of Job Shop Principles:

- large space required for the workshops and interim storage
- unsatisfactory material flow, i.e. long transport routes, waiting times and processing times of individual orders
- strong material returns
- big effort for management and control of the production
- poor overview of the production process
- higher capital requirements
- production control and work preparation become necessary
- increased funding application

The job shop principle can be applied whenever appropriate;

- if very different products are manufactured
- If the individual products have different workflows,
- If predominantly individual or small scale production are required
- If expensive resources are best used,
- When others should be shielded from certain jobs because of noise, vibration, heat, gases, vapors, fumes.

Flow Principle

In production based on the flow principle, the resources are set up in the order of production sequence

The flow principle can be divided into series production and the assembly line.

1. **Series Production**

   In series production the individual jobs are set up in the order of operations, but they are not connected together by assembly lines. The products go through production at their own pace. The next move is not based on a certain rhythm or pattern, but it can build up a buffer between the individual jobs.

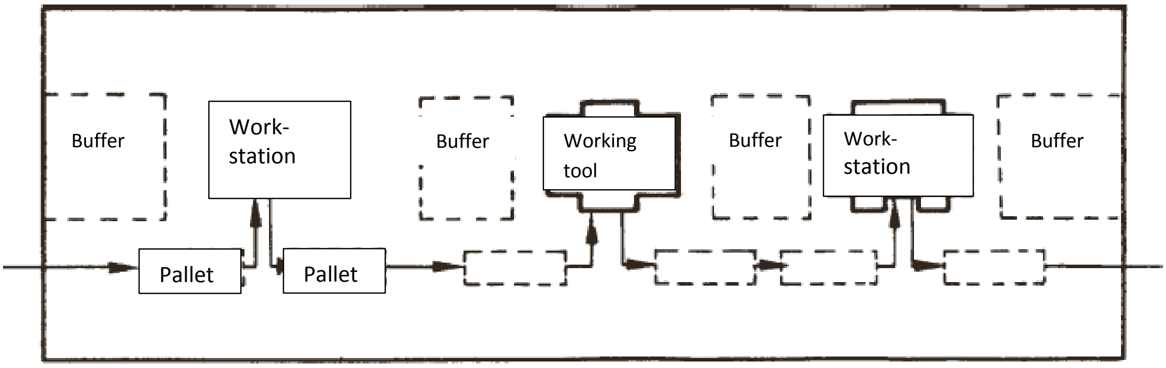


Figure 3: Series Production

Advantages:

- clear material flow
- low transport and waiting times
- Use of semi-skilled workers
- little disruptions during temporary loss of job

Disadvantages:

- high investment costs
- inflexible when changes in production

2. Assembly Line Production

In assembly line production the jobs are set up in the order of operations, but they are in contrast to series production connected together in sequence. The object to be processed flows from workplace to workplace. The flow through the individual workstations is coordinated so that every work tool is used.

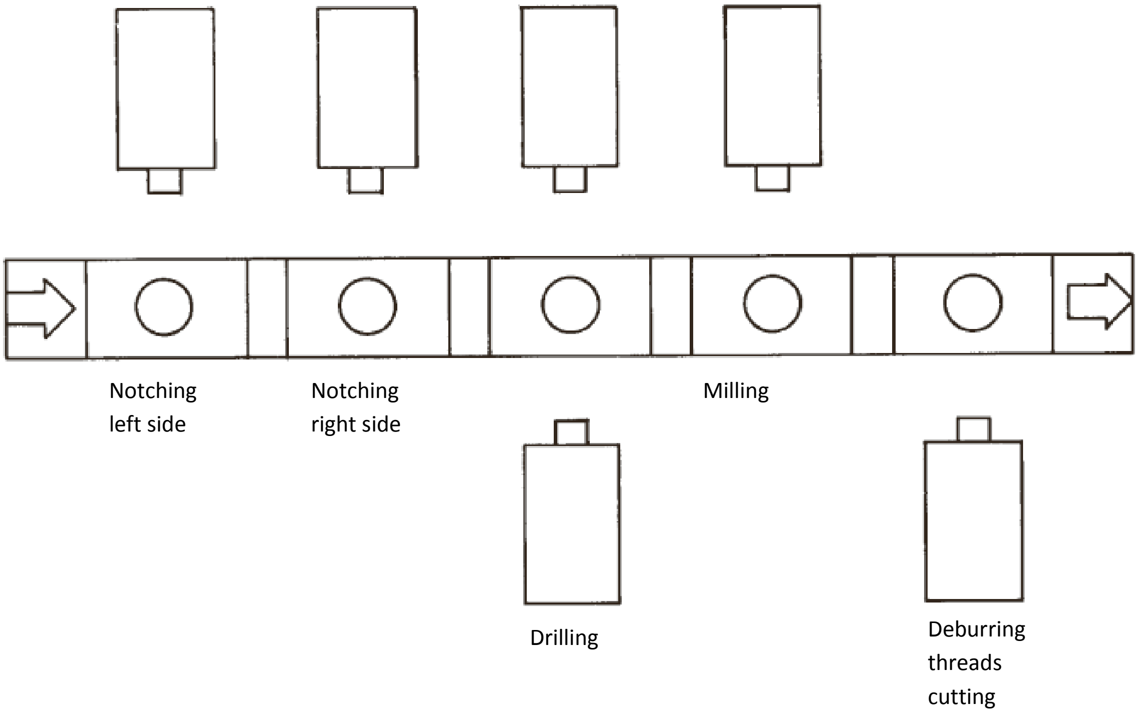


Figure 4: Assembly line production

In this production system either all the work from the first step to the last step or complex partial manufacturing pass through assembly lines. The conveyor belt transports the work pieces to be processed at regular intervals, while the work is performed by several workers in successive operations. Here the workstations are arranged next to the conveyor belt in the order of the prescribed performance tasks.

The speed of the assembly line is determined by the daily target quantity laid down in the production programme and thereby dictates the work piece and workflow (cycle time). The movement of the assembly line can be either continuous (independently running band), or it can be stopped at regular intervals (intermittently progressive time band).

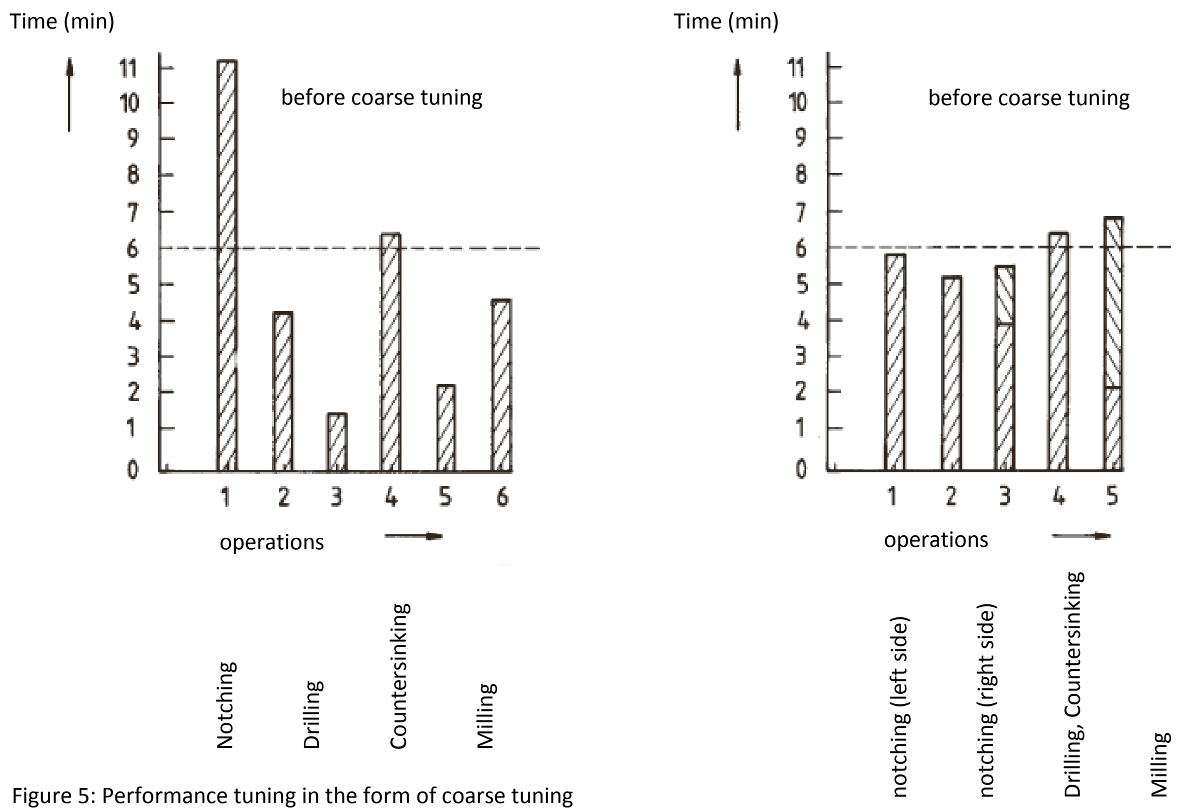


Figure 5: Performance tuning in the form of coarse tuning

A dependency on fixed cycle times only makes sense if similar products with standardized technical specifications can be produced in large batches. The time required for individual operations must be approximately the same, or it must be offset by a corresponding performance tuning. The purpose of performance tuning is to not only avoid excessive waiting times at the individual workstations but to also avoid excessive performance demands at other workstations.

Advantages:

- reduced delivery times
- increased efficiency as a result of lower capital commitment and faster material flow
- possibility of using efficient funding
- optimum workplace design
- higher productivity
- reduced space requirements
- lower transport costs per unit of the product
- effective monitoring of processes
- use of semi skilled workers
- the individual jobs are welded together to form a whole organization
- the individual recognizes that it is also depends on his work, if it is to run smoothly and efficiently

Disadvantages:

- monotone work due to the strong type sharing
- unilateral load of workers, thereby emergence of occupational illnesses
- lack of production elasticity
- high investment costs

When used correctly the assembly line production is a crucial way to increase labour productivity and reduce costs of the products. Therefore, it must be carefully examined, whether all conditions for an assembly line production are given, or can be created. However, the economic viability is crucial. It is only then possible if the following requirements for an assembly line production are achieved:

- a mature and production-friendly design of products
- a secure long term large production quantity
- the possibility of a breakdown of the production tasks into sub-tasks
- the spatial concentration of the work process in the smallest possible space
- a thorough preparation for production
- a secure supply and partial delivery in required quality, appropriate workforce
- Possibility of performance coordination

1.1.2.2 Group production

Group production does not focus as the workshop production on individual machining processes, but on certain combinations of specific work groups. In such concepts the manufacturing equipment and various processing methods are grouped together as required for the complete production of specific work groups. The structure of the equipment is an important prerequisite for the introduction of group work in manufacturing.

Advantages include shorter cycle times and product orientation. A disadvantage, for example, is that the equipment or work systems are not evenly utilised.

1.1.2.3 Manufacturing segmentation

The design of segments in production such as in the automotive industry came about with the spread of continuous flow production. What is however, new, is the attempt to optimize the entire production process. There are various approaches such as:

- **Strategic business units**: in the strategic planning of production the strategic business units or divisions are determined to be successful with completely different strategies depending on customer demand and competition.
- **Group work**: In the human resources and organizational development, the increasing focus on group work symbolizes such segments in the structure of the company as a social unit.
- **Production Islands**: production islands, production cells and group technologies present

The trend to segmentation in the technical preparation and the production technology.

Goals of the manufacturing segmentation:
- customer orientation and market impact
- reduced production spectrum
- integration of various functions

The principles of segmentation of production allow:
- optimization of material flow
- reduction of production stages
- reduction of stocks
- reduction of quality costs

1.1.2.4 Automatic production

In the automatic production, the influence of humans, depending on the degree of automation, is confined to setting up, loading, unloading, maintenance and monitoring of machines and installations. In a compound machine, multiple individual machines are coupled together (press line in the body shop). In a transfer line (fully automatic manufacturing locations) the material flow must be adapted to the produced quantities.

For individual or small production quantities multi-purpose machines are used which are spatially arranged by type. In this way, workshops with similar machines (workshop production) and jobs, such as scribing, turnery, milling and assembly are created.

The parts to be manufactured go through the workshops in the order of their respective operations (job shop principle), such as scribing, turning, milling and assembly.

For large quantities, it may be appropriate to arrange the jobs according to the order of the operations (series production).Single-purpose machines can be used here.
If the individual machines are connected by a mechanical support, it is then called flow manufacturing.

Flexible manufacturing cells (FFZ)

To extend, for example, a processing center to a work-piece handling, this machine type is called flexible manufacturing cell. In addition it is usually still connected to a host computer, also called a cell computer. This assumes monitoring functions for the handling of work pieces (such as incorrectly installed parts) and for the tools, such as service monitoring and broken tool monitoring. Additionally, the host computer controls a work piece measuring system. The FFZ is thereby, able to work independently for a long time. Thus, it creates the conditions for an unmanned shift. The monitoring systems detect errors on the machine and in the process.
Flexible manufacturing cells are used in series production with medium-sized batches, if the range of parts is limited. The pieces are either pre-sorted or delivered on pallets. Mainly, drilling, milling, and turning (flexible turning cell) functions are carried out.

The flexible manufacturing cells typically work in two shifts, but also often in a third unmanned shift. Before using a rotary cell, camera rings, for example, had to be produced in seven separate machining operations, which required seven operations of the thin-walled parts. The scrap rate was correspondingly high. Complete machining in only one operation will significantly increase the quality, decrease set-up time, reduce processing times and shorten lead times. As production can be done per order, the storage costs can be reduced (according to the documents of Traub AG, Reichenbach/Fils).

Flexible Manufacturing Systems (FMS)

If several NC machines use a common tool and work piece supply for the complete machining of work pieces, such a system is referred to as a flexible manufacturing system. In this process, measuring and assembly machines as well as material flow and information flow systems are linked. The advantages of flexible manufacturing systems over flexible manufacturing cells are the greater adaptability to changes and greater productivity. They are preferred for part families requiring medium-sized quantities.

In addition to a host computer, an additional planning computer is necessary. This assumes the central monitoring and diagnostic tasks. In particular, the tasks of a production computer can be included:

- Review of the work system (component stock, component transport, component storage)
- Verification of the tool system (downtime, tool breakage, tool requirement)
- Checking of the clamping systems
- Determination of the order sequence of lot size, specification, and delivery date (organization of rush orders)
- Provision of NC programs (DNC)
- Automatic quality control
- Output of various reports and statistics (such as errors, interference, data quality)

Flexible manufacturing systems basically consist of multiple processing units for the complete machining of work pieces. They have a common work piece and tool system, as well as a control system (DNC, PLC) and an information system (production computers, planning computers). FFZ is predominantly used for part family with medium-sized quantities.

Figure 6 shows the control panel of a flexible production system in an overview. The monitoring and control of the entire system is housed in a control station which is arranged over the island computers. From here, the operator can oversee the entire system in all directions.

Control level

Tasks of production computers:

- Order management
- Central tool management
- Tool presetting
- Planning functions, such as machine utilization, work piece carriers (pallets), tools
- -NC-Programm Management

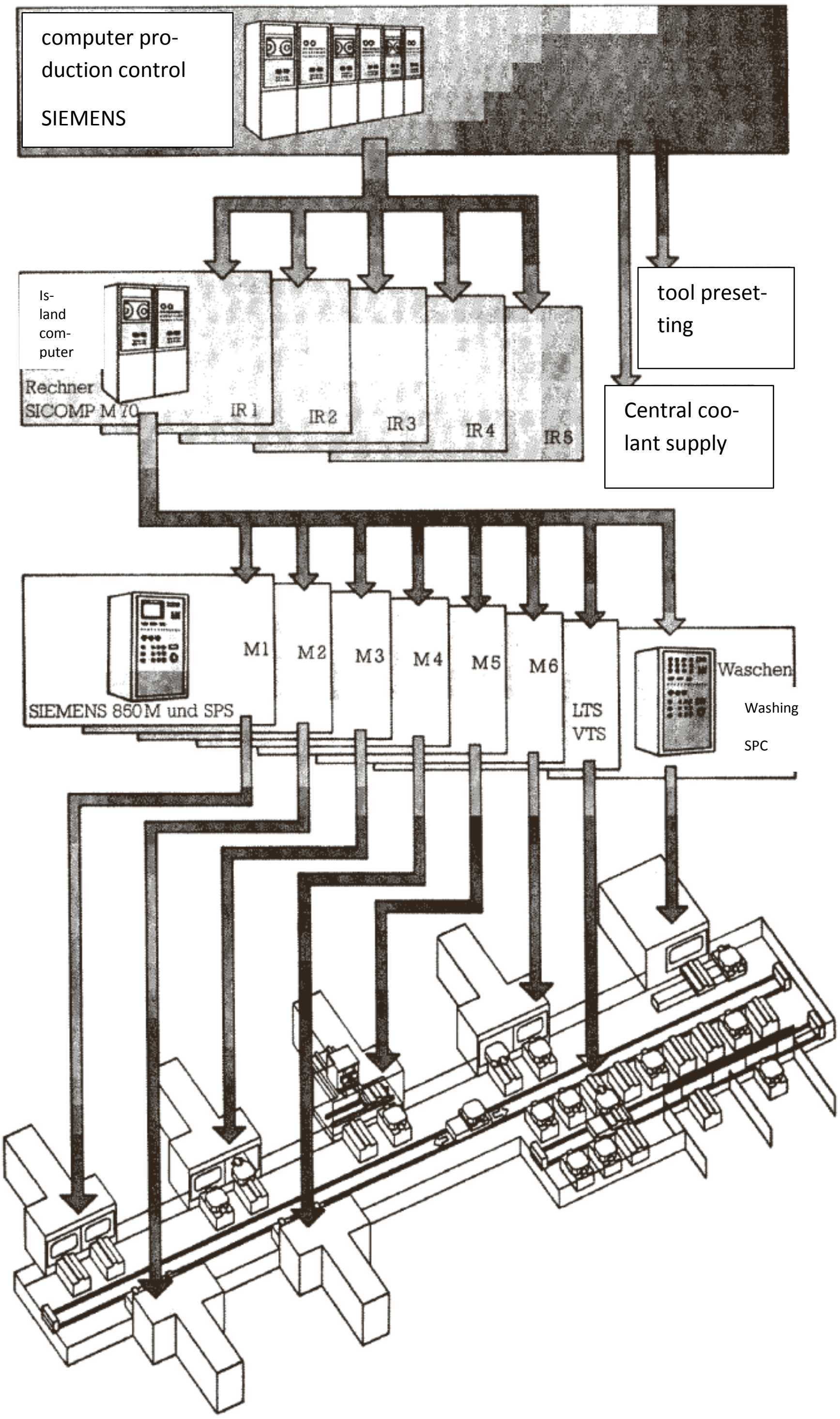


Figure 6: control panel

Cell level

Tasks of the island computer:

- Materials flow management
- DNC
- Coordination and monitoring of all associated components, such as clamping area, machine tools, transportation systems

Control Level

Tasks of machine control:

- Machine functions
- Tool life and wear and tear of the tools
- Diagnostic data

For example, Flexible manufacturing system for the production of screw shafts

With a FFS, 50 different screw shafts from 40 mm up to 140 mm in diameter and 300 mm to 1000 mm length should be produced in any batch size without an operator.

The following requirements are imposed on the system:

- complete machining of screw shaft from the rod until the finished work piece
- automatic conversion required when switching to another work piece variant
- automatic tool change for wear or breakage
- automatic quality monitoring with logging of measured data

The flexible manufacturing system consists of (in the order of processing) a CNC automatic sawing with an upstream rod magazine, a CNC lathe with disc-type-turret, work piece and tool measuring sensor as well as an external tool magazine, a CNC-screw and groove milling machine and a CNC external cylindrical grinder with measurement control. For the loading and unloading of the machine tool 1, 2 and 3 as well as the tool change a CNC gantry robot with two parallel grippers is used.

A work piece buffer is located in front of the screw milling machine and the external cylindrical grinding machine. The finished screw shafts are removed via a conveyor belt. A host compute, PC based, controls the entire flexible manufacturing system.

Material flow

- The rod sections are cut to length by automatic sawing machines and fed to the automatic lathes by the gantry robots. The automatic sawing machine provides rod sections requested by the lathe.

- The required cross-cutting, centering and turning of the shafts is done in two operations. The lashing is done by the gantry robots. Measuring probes, which are located in the tool turret, checks the accuracy of work pieces.

- After the turning operation the shafts are placed on a temporary buffer by the gantry robot, in order to be fed to the milling machine when needed. Here too, a quality monitoring with a replaceable measuring probe is carried out by inductive signal transmission.

- After milling, the shafts are placed by the gantry robot on a further temporary buffer and fed from there to the external cylindrical grinding machine. With a measuring head, the compliance of the grinding tolerance is monitored.

- After completion of the grinding, the finished screw shafts are transported via a conveyor belt for further use.

Tool breakage, in the turning and milling machines is checked by appropriate monitoring devices (such as infrared monitoring).If necessary, the replacement tools are taken from the magazine and loaded into the machine and checked for correct positioning by the gantry robot.

Control Panel

The order volume for a given period (day, week) is passed from the production planning system to the host computer of the flexible manufacturing system. This then assumes the following tasks in production:

- Order management with planning of the sequence of the orders taking into consideration rush orders.

- Control of the production process of the manufacturing cell, i.e. the synchronization of material supply, materials processing, finished part measurement, and material transport. In addition, the master computer program monitors the sporadic tool change by wear and tear as well as the systematic change in another variant of the screw shaft. The sawing and feed magazine is controlled via touch recognition and a length measuring device.

- Monitoring function of the individual processing machines (such as engine failure, failure of the cooling lubricant pump).

- Monitoring of the transport of raw materials and parts.

- Logging function (quality protocol, incident reports, and reports of used tools).

Conventional Transfer Lines

The use of conventional transfer lines is done for large numbers if there is the same manufacturing engineering requirement, as in the example of part families (engine blocks, transmission housings) a larger number of operations is required at the same time. These requirements results in the construction of the transfer lines. There are usually special machines that are arranged either parallel or/and in series and connected by a common work piece transport system. The transfer of the work piece from processing station to processing station occurs at a certain cycle time which is determined by the longest working cycle.

The typical range of the transfer line is due to the large numbers in the automotive industry. In general, the work pieces can be put together according to the modular principle of construction units, which represent closed assemblies. The processing stations of a transfer line can be rigid or loose chained.

Rigid Concatenation/Chain

Processing stations with concatenation system have a common control. The machines used are almost always special machines. The work piece is performed on at a continuous and uniform cycle time which is determined by the slowest working cycle. If an error occurs in a processing station, the entire transfer line is comes to a standstill.

Loose concatenation/Chain

There is no common cycle time, because the individual processing stations have work cycles, which are independent of one another. This results in greater freedom of movement and flexibility in the arrangement and placement of the individual processing machines. However, work piece storage and a fault buffer must be planned between the individual stations. When errors occur in the production process, upstream and downstream processing stations can continue as long as the capacity of the error buffer is sufficient.

In practice, series machines can be connected through the loose concatenation. It is also possible to combine rigid and loose concatenation whereby a part of the system is rigidly chained and with another part loosely concatenated. As a result, the advantage of a short work piece passage can be combined with the bridging of downtime by a buffer.

The high investment cost of conventional transfer lines require a long period of amortization. The shorter model cycles for example in the Automotive industry is guaranteed an amortization of such facilities not often. This led to the requirement that transfer lines must be designed for an increasing number of work piece variants. This goal can only be met with flexible transfer lines, as well as the future in the mass production transfer lines more flexibility is required when converting to component options.

The high investment costs of the traditional transfer lines require a long depreciation period. An amortization of such assets is often no longer ensured by the shorter model cycles, such as in the automotive industry. The led to the requirement that transfer lines have to be designed for an ever-increasing number of work piece variant. This goal can only be fulfilled with flexible transfer lines. Even in mass production, transfer lines with more flexibility are required when converting to alternate component options.

Flexible Production Line

The number of parts to be manufactured in a specific unit of time with low manufacturing costs per piece determines the requirements for a flexible production line.

- Suitable for medium-sized batches of 500 to 5000 units
- Processing of part families or part variants
- Short changeover times
- Short processing and cycle times
- High precision machining
- Central machine operation
- High operating reliability

Flexible production lines are currently used in metal forming technology, in the machining and in the assembly area, when similar parts (part family) medium to high volume (30 to 600 pieces per hour) are required. The frequent job changes for these batch sizes require a quick change-over and thus a higher degree of flexibility. This is also necessary if future product changes are already foreseeable, so that a change-over to the later product is possible without much difficulty or expense.

Machining units

Here largely standardized components are used. NUMERICALLY controlled horizontal tool spindle units offer the most flexibility in three axes. These units can be equipped according to the machining sequence or the variety of types with tool magazines. Requirements for all machining units are a continuously variable main spindle drive. In order to reduce the processing times, multiple spindle heads or drill head turrets are often used. To monitor the processing quality in the individual processing stations a probe can be loaded which causes a tool change or a tool-edge correction.

Tooling

New or different tools are used when the tool life is reached or if there is tool breakage or if a tool change is needed. This can be done manually for long service life or for a rare change of tool type. The changeover requires a longer period of time and it can then also influence the setting of different screws to new positions as well as the adjustment of the clamping device for the new work pieces. With frequent type changes (small batches) or tools with a short service life, the tool change occurs automatically. Here, the tool magazine can be integrated into the processing unit or central tool storage can supply the entire transfer line with tools. In this case, the tool storage and tool changers are eliminated in the individual processing stations. The used tools and new tools for the next job can be changed during production in the central magazine or it can be removed. If the tool magazine is integrated into the processing unit, chain magazines or disk magazines with 4-40 tool places can be used.

Handling of Work Pieces

Because of the flexible transfer line, a direct flow of material is present which often results in lower demands being placed on the work piece transport system, as would be in the case of flexible manufacturing systems. For work pieces with the same shape, but with different surfaces or drilling images, free transportation between the individual processing stations is possible. The various pieces are always fixed and clamped in the same locations (e.g. cylinder heads). A gantry loader can, for example be used in this case, which with corresponding grippers can bring the work pieces to the processing station. For different shapes, but the same central holes or clamping radii work piece carriers are used in which various work pieces variants can be included and clamped. They don’t have to be modified if there is a type change. If the receiving and clamping conditions of the work piece to be processed are different then a convertible or a specially designed work piece carrier is used. In a synchronous (concurrent) transport all work piece carriers are simultaneously (synchronously) brought by a tact rod to the next processing station. In an asynchronous (uneven) transfer, the transport of the work piece carriers between the individual processing stations takes place on powered roller conveyors. In this case, buffer zones must be considered. The transport of the work piece carrier from the end to the beginning of the transfer line is done on a separate return path.

Control technology

Due to the direct material flow in the transfer line, the software related cost control is significantly lower than for the flexible manufacturing systems, since the flexible work piece transfer is eliminated. However, great value is placed on minimal downtimes and short changeover times, automatic tool change, high positioning accuracy, tool time monitoring and processing security (stopping the machine in tool breakage, transgression of cycle time). These requirements must be implemented in terms of control. Added to this is the good operability of the system by the staff. This is achieved through local control panels for the individual processing stations, as well as through a central machine control panel. Single- and automatic operation, operation via an on-screen information system, graphical representation of motion sequences, machine monitoring and error diagnosis system are state of the art today.

For example: Flexible production line for the manufacture of compensation packages

For the automatic production of differentials gears, required by the automotive industry in large numbers, a flexible transfer line was developed. This plant is used for the complete machining of parts from GT-55. 80 parts per hour (cycle time 45 sec) are manufactured with the highest precision. The transfer line consists of 29 stations, which are further subdivided into two areas. While in the first area the pieces are processed one after the other, in the second area because of the different cycle times, two pieces must be processed at the same time. The plant is about 29 M long and about 13 meters wide. The total installed capacity is 370 kW. Sinumerik control systems were used for CNC machines of type 810 ME and TE 810 (.Siemens).

In particular the following processing steps must be performed:

- turning the flange surfaces
- unscrewing and over-tightening of the front and rear hub
- turning the intake diameter
- turning the outer diameter of the hub
- working the inside shape of the ball
- drilling of the eight holes of the flange and the two inner holes
- tapping the eight holes of the flange and the two inner holes
- manufacture of function holes
- manufacture of the contact surfaces for the function holes
- finishing of the hubs and the function holes
- finishing of the inside shape of the ball
- manufacture of the external dimensions of hub and flange surfaces

Optimization of Organizational and Operational Structures of the Master Data

The production line consists in principle of an un-machined parts store, processing machines with measuring equipment, the transport system (Portal gripper, lift and turn conveyor), an intermediate buffer to bridge system-related downtime, and a finished parts store.

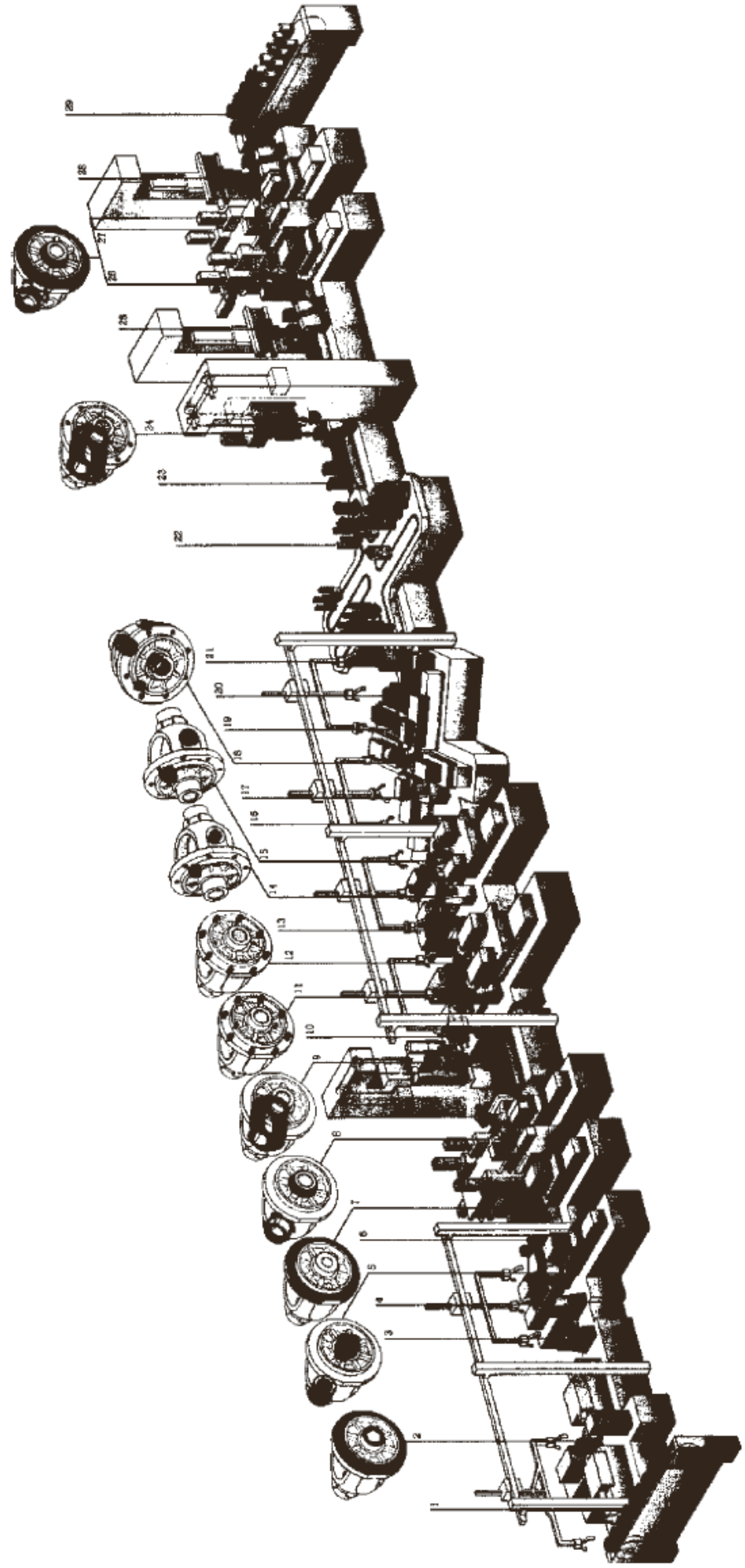


Figure 7: assembly line

1.3.3 Maintenance operation structures, maintenance operations (DIN 31 051)

Due to the ever-increasing investment costs for machine tools, the loss of use of a system represents a major cost factor. Therefore, the goal of maintenance operation measures is to ensure that machines are production capable in terms of function and quality. At the same time, the operator safety must be guaranteed. Maintenance of machine tools includes the following tasks:

- maintenance assurance at nominal technical condition
- inspection determination of machine
- repairs restore the nominal specified condition

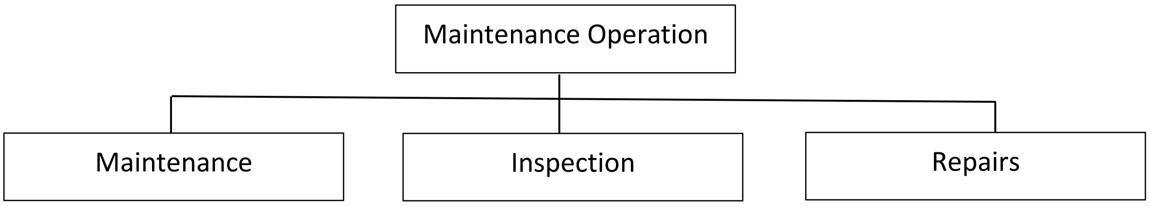


Figure 8: Maintenance Operation Structures

The performance of these tasks is usually carried out by an independent maintenance department, which in addition has a tailored spare parts inventory.

1.1.3.1 Maintenance

Maintenance must be carried out according to the manufacturer’s instructions at specific intervals. These rules include guidelines for regularity (e.g. every three months) and the time limit (e.g. by year end) and the maintenance tasks. The work serves for the preservation of the quality of the products to be manufactured and the reliability of the machine.

Maintenance work, for example:

- check system pressure of hydraulic systems
- check the coolant and replace if necessary
- management of the feed slide adjust
- lubrication instructions in accordance with lubrication schedule
- perform cleaning of the machine tool

1.1.3.2 Inspection

It includes all considerations to identify and assess the machine of a machine tool and serves the purpose to identify necessary maintenance measures in time. The intervals between the individual inspections depend basically on the wear and tear characteristics and on the importance of the component for the entire machine. This is determined by the manufacturer's recommendations and the company’s own operating experience.

1.1.3.3 Repair

It is used to restore the desired state of the machine and is divided into:

- Repair by reworking (e.g. guided rework)
- Repair by replacement (e.g. change a cooling lubricant pump)

In order to not affect the production process too much, a sensible plan of repair work is required which must be timed to coincide with the life of the machine and the requirements of production.

After the overhaul, a damage report is prepared, which must include the repair work, the date of the repair and any other special events (such as deviations from the manufacturer's recommendations).

1.1.3.4 Preventive maintenance

Machine tools are subject to a natural wear and tear. Thus, the quality characteristics of the machine tool and hence their products are worsened. Before the minimum quality requirement is reached, repairs must be carried out as preventive measure. Through repeated inspection of the machine tool, a characteristic of the quality in the form of a graphic (see Figure 1.28) can be recorded. This graphic represents the degree of wear and tear of the components of the machine and thus the decline in the quality.

The intersection point between the minimum quality requirements and the acceptance trend of quality represents the instance at which the required quality can no longer be achieved. From the knowledge of this instance, and from experience, a date for the preventive maintenance can be determined in order to revert the machine tool back to the desired state.

The following maintenance structures are determined:

1. Central maintenance workshop

Advantages:

- optimum utilization of equipment
- facilitation of the spare parts and auxiliary materials supply
- staff adaption to situational requirements of the operation
- central planning and control according to urgency and needs of management
- increase the quality of maintenance
- continuous maintenance data and analysis
- facilitation of short-term implementation of weak-point analyses

Disadvantages:

- various production programs make it difficult to keep track of their condition
- long travel times of maintenance personnel in the event of a malfunction
- decentralized maintenance workshops of operational areas

2. Decentralized maintenance workshop for operational areas

Advantages:

- low travel times of maintenance personnel in the event of a malfunction
- good overview of the technical condition of the maintenance facility
- good cooperation between maintenance and production staff

Disadvantages:

- high investment costs (multiple maintenance workshops in operation)
- increased spare parts and auxiliary materials storage of same parts and auxiliary materials
- administration and management (update) by technical means of communication

3. Decentralized maintenance workshops (base workshops)

Advantages:

- reduction of downtimes of machines and equipment by the constant presence of maintenance staff and their commitment
- familiarity of maintenance personnel with the susceptibility to failure of the equipment
- immediate access to spare parts

Disadvantages:

- extensive repairs only possible by contractors
- high investment costs (multiple maintenance workshops in operation)
- increased spare parts and auxiliary materials storage of same parts and auxiliary materials
- administration and management (update) by technical means of communication

4. Decentralized maintenance workshops (special workshops)

Advantages:

- for special repair procedures for a wide range of machinery and equipment;
- sale of these maintenance services within their own business

or as an external service for other companies; as a result, the facilities can be used better

Disadvantages:

- attachment to a larger number of specific machines and equipment,
- with increased number, transport distance and costs are increased

2. PLANNING

2.1 Scheduling

The scheduling is the definition of start and finish dates for the task performance in certain work systems. As a result, it should be possible that the overall task can be completed by the specified target date. For the execution of the task, the scheduling plays a major role, because missed deadlines can mean penalties as well as serious long-term loss of clientele effect.

The scheduling sets the exact date and often even the time at which a sub-task should be completed or must be terminated. The dates set out in the schedule are therefore, the basis. The data obtained during the planning, such as assignment of operations to specific work systems, spatial and temporal order, are used as input data in the scheduling.

If detailed networks or bar charts have already been created in the context of the scheduling, a determination of dates is possible. In most cases, the operational life is more complex since additional conditions and constraints must be met.

Normally, multiple parallel tasks compete with each other to be completed. The set dates must be adapted as a result of the new circumstances due to interruptions such as illnesses, damage to machine, material delays, etc. The goals are a consistent utilization of capacity and short lead times. The prerequisite for this is that the staff and the resources are used according to their qualifications and specification. Only in this way, can the costs be kept to a minimum.

The conditions for the determination date or planning are that the performed tasks are specified. Therefore, material, capacity and information needs are known. Furthermore, material stock and sufficient capacity as well as the longer term duration is assured.

In the area of production, the scheduling of tasks is always for specific jobs. Completion deadlines arise mostly from the delivery date of the complete finished component. This date is either required by the customer or set during the processing of the offer or fixed in the production program.
The task of scheduling is now, the new date arising from the order deadlines in production so that the deadline is observed. Attention should be paid to the specific quantity of products, components and parts including the necessary preparatory work for production. Naturally as little material as possible should be used and stored for a brief time only. In addition, the capacity should be fully utilized but it should also not be overloaded or have idle time.

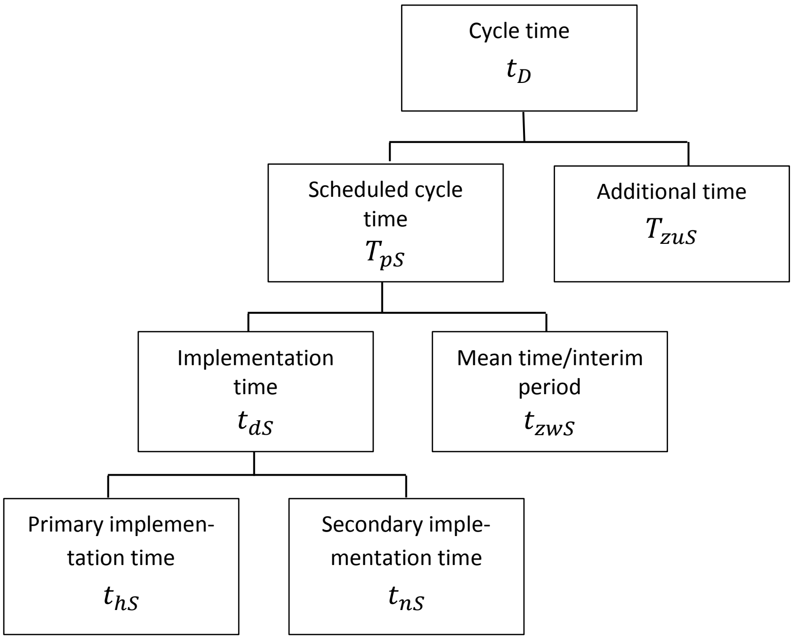


Figure 9: Breakdown of the cycle time according to REFA

Explanation of terminology:

The **cycle time** is the target time for the performance of a task in one or more specific work systems.

The **scheduled implementation time** consists of the sum of the target times of sequential sections which are required for the scheduled primary and secondary execution of a task, and the meantime.

The **mean time** consists of the sum of the target times, in which the implementation of the scheduled task is interrupted. The mean time includes the wait time and the transport time.

The **additional time** consists of the sum of the times that are required in addition to the scheduled execution of tasks.

In manufacturing plants, in particular, determination of the processing time is relatively easy because the tasks within organized processes consists of work schedules and target times and the workflow structure is a simple succession of workflow sections. Due to deviations from the planning requirements it may be necessary to shorten the cycle times.

Example to shorten cycle times
- smaller lot sizes require shorter implementation times
- consolidating of process sections, such as complete machining of a work piece on a machining center
- shortening the interim times through better planning and management of material and information flow
- overlapping process section e.g. before the entire lot is finished in the lathe, induction hardening of the bearings on the already finished waves can begin in the hardening shop.

The schedule planning described in the following three sections apply primarily to production according to the job shop principle. This work is customer-oriented (workshop production). In the assembly line production with the constant sequence of operations and almost uniform utilization of capacity, the scheduling problem is largely solved by the cycle time. The main focus is the planning of material requirement, in particular procurement and supply.

Generally, three types can be identified in the schedules of customer-oriented production:

1. **Order based scheduling**; Here, only the individual order is taken into account. Other, competing orders are allowed bearing in mind the capacity load. This planning is applied to large projects if sufficient capacity exists.

2. **Capacity-oriented scheduling**; the mutual influence of competing orders is considered. Again the capacity load and capacity restrictions are included in the planning.

3. **Integrated scheduling;** in this case, the availability of all inputs such as materials, measuring and test equipment, tools and documentation, is taken into account. It is a capacity-oriented implementation.

The individual types of date calculation differ significantly in their task.

Scope/Schedule	**Job-oriented**	**Capacity-oriented**	**integrated**
Capacity leveling		X	X
Order control		X	X
Material availability			X
Availability of tools, test equipment			X
Availability of working documents			X

Figure 10: Scope of the different time schedules

But in practice combinations are also possible, e.g. with adequate capacity in individual work systems; order-oriented and for bottleneck work centers capacity-oriented or integrated. In the integrated scheduling, in contrast to the combined scheduling, the availability of the material is also taken into account and priorities for all jobs are set.

2.1.1 Job-oriented scheduling

The order-based scheduling is to determine the start and finish dates for the task performance in specific work systems. Thus, the existing capacity load and capacity limits are not considered. This type of planning is called static scheduling, lead time scheduling
or project scheduling.

The result is the order-based schedule. A short-term capacity adjustment will not take place. This is usually done, if necessary in the connected second stage; capacity-oriented scheduling. The order-based scheduling is then sufficient, if capacity gaps which occur at short notice, due to alternative tasks, overtime or similar measures can be compensated.

An example of the schedule is shown in the diagram. Start and end dates for the individual tasks are shown. The dates are adapted to external requirements such as customer presentation and the delivery date. However, it does not include for example, capacity gaps due to the holiday season in summer or by necessary equipment maintenance.

			↓ Presentation of design							↓ Delivery date
Product development	▨									
Product design		▨								
Production planning			▨	▨						
Procurement of resources				▨	▨	▨				
Determination and procurement of material						▨				
Manufacturing of components				▨	▨	▨	▨	▨		
Group assembly							▨	▨	▨	
Final assembly										▨
	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct

Figure 11: Start and end times of a fictional production. Requirements: set by external specified deadlines.

Often, the order-based scheduling is complemented by the fact that for a workshop order regarding a shortage of capacity requirements, a capacity-oriented scheduling system is determined.
Labour shortages are those systems in which there is a high level of employment but where a shortage of capacity exists as demand is higher than the reserves.

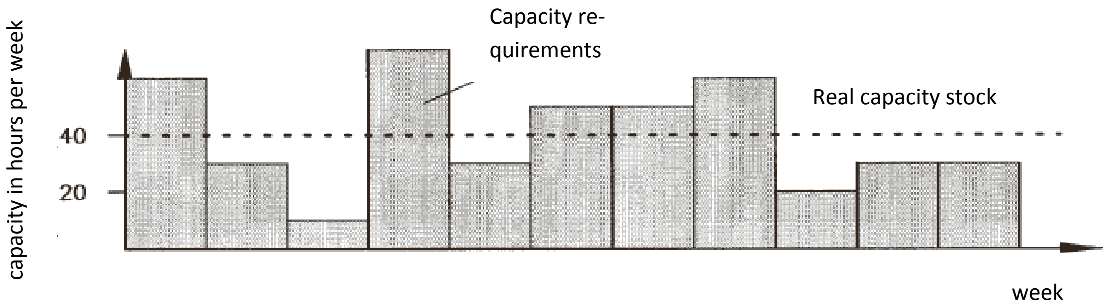


Figure 12: Capacity requirements and reserves in a single system in order-orientated scheduling and competing orders

If the order-based production is based on scheduled deadlines, then the available capacity should be taken into account in these plans. However, the allocation of capacity by other orders is not taken into account in scheduled deadlines. It is therefore, foreseeable that if the deadline can not be met the processing time is reduced. This is possible by reducing the interim times, by overlapping, splitting and batching of operations. As a rule, the interim times are not too generously sized and the impact on other jobs must therefore, be considered.

2.1.2 Capacity-oriented scheduling

The capacity-oriented scheduling is to establish initial dates and finish dates for the task performance in certain work systems. This takes into account the existing capacity loads and limitations as well as the mutual influence of different tasks or jobs.

The result of this planning is the order-related appointment list.

The result is a work system-related appointment list, from which by using certain priority rules, the order and execution of the tasks can be derived.

The priority rules are agreements on the sequence of the execution of multiple tasks or sub-tasks through a working system. This can be based for example, on the order of receipt, the delivery date, the contract period, the turnover, missed deadlines or possible penalties.

The more different and independent orders processed entirely or partially in the same operating system are, the more important is capacity-oriented scheduling. Competing orders result in the consideration of capacity, in contrast to the order-related planning, and not to postponements or delays of deadlines.

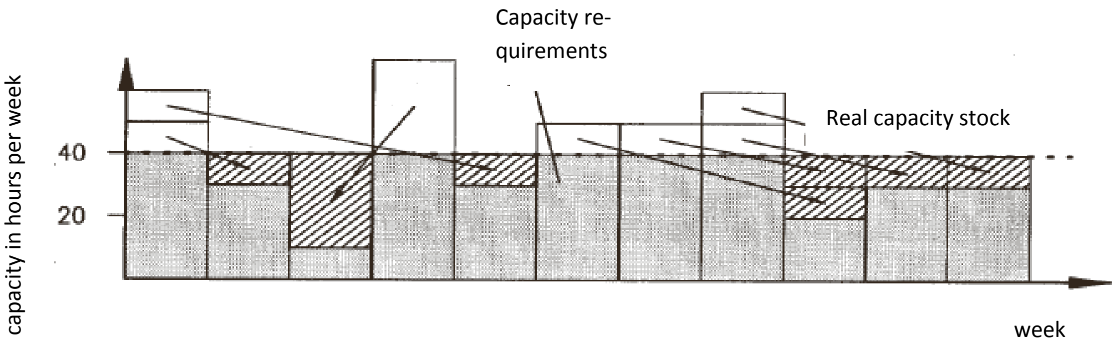


Figure 13: Capacity for compensation within the capacity-related scheduling

The coordination of time-bound capacity of stock and needs is at the core of capacity-oriented planning especially in a production with highly mechanized, expensive machines. This agreement can be done within the framework of scheduling only with regard to temporal and technological capacity levels. With regard to temporal adjustment, the demand peak in times of excess capacity is postponed until a match of demand and reserve is found, usually with a small reserve of capacity adjustment.

The temporal adjustment, however, requires that the order in question is a non-critical process, so that task or sub-tasks may be moved.

Often, the order-oriented planning is supplemented by the fact that for a workshop order regarding a shortage of capacity determines the capacity requirements, i.e. for this system a capacity-based scheduling is carried out. Bottlenecks are those systems, in which there is a high level of employment but a shortage of capacity, demand is higher than reserve.

However, exceeding capacity limits must constantly be observed. Ultimately an increase of the capacity must be made in the long term. In the short term however, the scope of capacity can also be utilized.

For example by:

- Overtime or additional shifts
- Weekend work in the form of overtime
- Employment of temporary staff (part-time or contract workers)
- Sub-contracting of jobs or tasks
- Technical shift to less suitable machines

These measures always cause additional costs, in the case of the first two points, pay scales and company-based agreements must also be respected. It is therefore, not advisable to constantly use this leeway. Rather it should only be used in the event of a failure.

The form capacity-oriented scheduling is complex. The requirements per period must be carefully planned and carried out for each individual or partial capacity. For each job, the capacity requirements must be determined and compared with the reserves. In order to meet deadlines, this scheduling must be frequently repeated and at short intervals, e.g. weekly. This can only be done by hand for individual capacity units. This task requires a powerful computer.

On the whole the capacity-related scheduling is:

- current workflow charts
- precise knowledge of the capacity reserves incl. possible capacity utilization
- clear identifiable orders
- functioning feedback on the occupancy i.e. in advance the load and the work in progress

2.1.3 Integrated scheduling

The integrated scheduling consists of the determination of start and finish dates for performing tasks in certain work systems, wherein the existing capacity load and the mutual influence of various tasks or jobs, and also the availability of all resources needed for the production are taken into account.

In determining the date of the capacity-based scheduling, the availability of all inputs is taken into consideration. The most important inputs for the implementation of production tasks are: material, equipment and tools, measuring equipment and test equipment as well as working documents such as drawings, parts lists, material cards etc.

As part of the integrated scheduling, planning and control data from sales, design, engineering, purchasing, warehouse, production planning and control, equipment design and manufacturing, quality, manufacturing and assembly are linked. This requires a well designed structure and process organization with a fast and smooth flow of information. Here, the use of a high-performance, networked computer is even more important than in capacity-oriented scheduling.

While the termination of an individual order appears easy, this changes when the orders are multi-level. The more a job is divided in order to optimize the processing time, the more likely is the mutual blocking of work systems. Moreover, the coordination of the manufacturing steps on multiple machines with possible supplies is not easy.

Furthermore, external interference or disturbances are problematic. Even an unaccounted public holiday in a different state can affect the availability of material; capacity loss due to damaged equipment, staff shortage due to business meetings or illnesses can easily require a complete re-planning. For this reason, the scheduling should not be classified as a rigid, completed task, but a continuous task, which must respond and adjust to disruptive incidents.

2.1.4 Influencing factors on the scheduling

The temporal control of production encompasses all measures which serve a planned schedule control of the production, with the aim to ensure a timely completion of all individual orders and at the same time provide the best possible utilization of production facilities.

The majority of all work on the holding is time bound. Whether it be in purchasing, sales, accounting or production, the work must be completed by a certain date; otherwise it would either be worthless or futile or result in a delay in the completion of other tasks.

Within the production area, the deadline date plays an important role. Compliance with the production dates is part of the proper execution of the order, and any failure to meet the deadlines can have serious external as well as internal consequences.

At the same time, the date determination in production is particularly difficult, because a large number of factors affect the timely completion of each individual order, on which the operation has very little or even no effect at all:

- timely delivery of the ordered material
- time limit and order composition of individual orders
- special requirements of customers
- capacity changes
- fluctuations in performance
- overtime

From the list of these factors, which make up only a small part of the forces governing the schedule system, the scheduling is not a one-time act, but is subject to constant refinements, controls and new instructions.

There is a distinction between **rough-schedule planning**, detailed time-scheduling and deadline supervision. The rough-schedule planning always takes place prior to the start of production. It is used to determine the basic dates of the individual work processes. The basic dates include the period within which a certain work process begins and ends. Compliance with the basic dates ensures a steady flow and the proper sequence of all working sections required to execute a specific order. The best way to illustrate the results of rough-schedule planning is to produce a scheduling overview.

The purpose of the **detailed time-scheduling** is that the individual operations that make up the work sections, are scheduled is such a way in the current production, that on the one hand the basic dates are met and on the other hand, the operating equipment is uniformly fully utilized.

Detailed time-scheduling is based on the work, work sequence and cycle schedules as well as on the results of the rough-schedule planning. It aims at establishing the start and the end dates of individual operations.

A detailed time scheduling is only possible in close connection with the machine and staff planning.

It is important to note that:

- the basic dates of the rough-schedule planning be respected
- the operating equipment is uniformly utilized
- minimal changes of operating equipment are necessary
- the running sequence of the operations is secured, so that no downstream work stages have to wait on the completion of work in earlier stages

The deadlines of each individual order and all its operations together with the time utilization and occupation of the machines and jobs are to be harmonized.

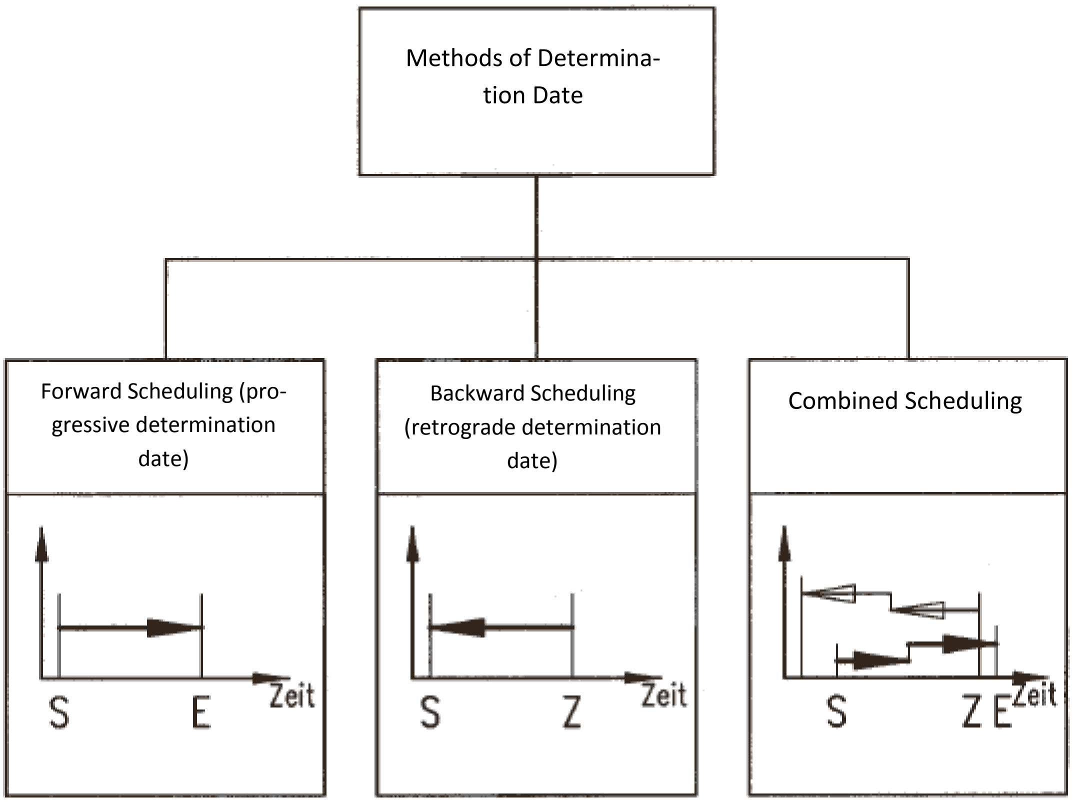
The **deadline supervision** finally, has to monitor the compliance of all established dates continuously, determine missed deadlines as early as possible and either eliminate interruptions and delays of work by corresponding new instructions or to reduce to a minimum.

2.1.5 Scheduling methods

In determining the date, three methods can be distinguished:

1. **Forward scheduling**
2. **Backward scheduling**
3. **Combined scheduling**

Using these methods the start dates, final dates, delivery dates and start and finish dates and interim dates of sub-tasks can be determined.



S = Start date
E = Deadline
Z = Target date
Zeit = time

Figure 14: Methods of Scheduling

In forward scheduling, all start dates and finish dates of each task and the end date of the overall process can be determined on the basis of the starting date. As additional key parameters like the default or execution time for the various work systems, the interim or transitional periods, and the sequence of sub-tasks are also considered. This scheduling is based on the product breakdown according to production levels.

At the same time, components manufacturing and also the installation can be performed in an overlapping task. Manufacturing of all parts will commence on the start date. Therefore, the intermediate parts must be stored relatively long. Before the actual installation begins, a large capital commitment occurs. In addition, capacity limits should be considered. Thus, split times can arise, which increases the cycle time. The target date, as a result is later than the delivery date.
In backward scheduling, all finish dates and start dates of each task and the start date of the overall process are separated on the basis of the target date. The procedure is similar to that in forward scheduling. It should be noted that all dates are the latest feasible deadlines. This eliminates a whole range of additional time and costs, as well as continued storage time and cost.

However, if errors in the process occur, the risk that deadlines are not met is greater in backward scheduling. A larger number of processes in comparison to forward scheduling are almost automatically time-critical.

A comparison of the scheduling is given in Figure 15.
The length of the arrows corresponds to the storage times.

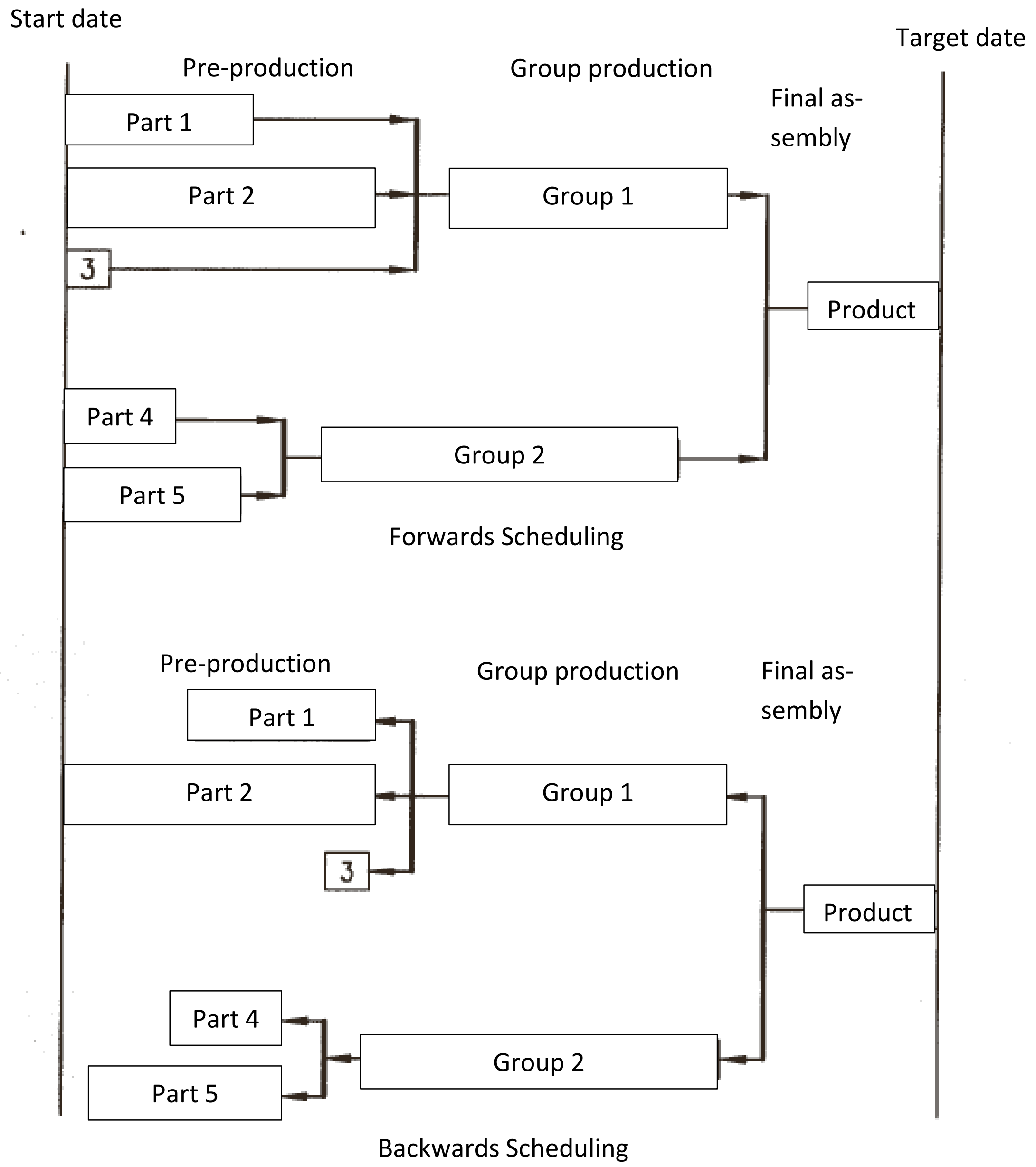


Figure 15: Comparison of Forwards and Backwards scheduling

In the combined scheduling the start and finish dates, based on the target date, are gradually determined by alternating backward and forward calculation. In backward scheduling, a reversal of the forward direction of time may be necessary, if for example, the backward calculated start date of an operation is before its earliest possible start date.

The earliest possible start date can for example, be determined by:

- the present day
- the date of the availability of material
- the date of the capacity availability
- the expiry date of the previous operation

In the combined scheduling of multi-element products, the production structure of the target date of the product is determined by starting backwards up to the components. In this way, a group is formed. The start and finish dates of the group are set and subsequently the dates of the group in the next, underlying production level. Then, if necessary, groups in the higher level of production are re-scheduled. In this way the schedule plan is systematically formed; bifurcation for bifurcation.

If the earliest possible date in this procedure is not reached, the scheduling direction is then reversed. The earliest possible date is now the starting point for the scheduling of the following processes, which results in a forward scheduling. This ranges from the affected sub-task to the end date.

At the same time, all options are used to reduce the cycle time in order to either minimize the excess of the target time or if possible to prevent it altogether. On the basis of the newly acquired dates a backward scheduling is once again carried out. This may also affect groups and parts that were already allocated start and finish dates in the previous scheduling.

Date determination can now be DP supported, for example, by so-called electronic planning boards (control stations) in simulation games. However, extensive input data such as shift times, work schedules, capacity rates, etc. and the entry of transaction data (orders) are essential. The programs for the determination of the date are often offered as modules of MRP systems.

Summary

In the manufacture of products deadlines are either fixed or must be determined. Here, the scheduling task is to coordinate the timings of each job so that the deadlines can be met. At the same time, it is necessary to know how long the cycle time is, what priorities (job-oriented, capacity-oriented) are important and which methods of scheduling are applied.

2.2 Capacity Planning

The aim of capacity planning is to ensure that for the implementation of operational tasks the required personnel (human) and equipment (machine) as well as the required quality and quantity is made available at the right time and place.

Thus, capacity planning is the prerequisite for the operational tasks to be carried out economically and people-friendly. Capacity planning is usually defined for medium to long-term periods, which are derived for example, from the production program planning. Consequently, the planning results are often uncertain regarding the actual time of realization under present circumstances.

Capacity planning tasks include the following points:

- calculation of capacity requirements
- determination of the capacity reserves
- adjustment and reconciliation of the capacity reserves to the capacity requirements
- planning and procurement of personnel and equipment
- use of capacity.

2.2.1 Importance of Capacity

- Resources

The resources are also called technical equipment or tooling. It covers for example, machines, tools, equipment and measurement and test systems.

The selection, as well as the adoption of appropriate production resources has already been made during the preparation of the work plan and entered in the task list. Thus for a particular manufacturing process, the appropriate production equipment (machines, tools, jigs and gauges) is selected. Therefore, it is necessary that these are know by the production engineers. Of great importance for the economy of production is that disruptions of the production process caused by machinery breakdowns, tool breakage, too short down times and inadequate provision of jobs are best avoided whenever possible. Therefore, it is necessary that the management, storage, maintenance, and repair of production equipment run smoothly.

Since production equipment, especially in high capital-intensive production, results in high investment and corresponding costs such as depreciation, interest, and maintenance and repair costs, more attention must be given to the development of these production costs. This however, requires an optimal medium of production organization that involves planning, procurement, storage, supply, maintenance and cost control. Therefore, a close cooperation between the schedule planners, production designers, the production administrators, the engineers and foremen, the toolmakers, and the cost computers is essential. In addition, an intensive exchange of experience, better consumption controls, a well-functioning system of improvement proposals, an internal standardization of production equipment and preventive maintenance must be implemented.

- Staff

The goal of good HR planning is to ensure that employees are available for the company to fulfill its mission at any future time. To achieve the set targets, it is necessary to draw up plans on the number and qualifications of personnel requirements. If the planning of personnel fails, the business objectives can not be achieved.

Capacity (people and equipment) both from a business as well as a technical perspective is an important factor which is essential for the success of the operation and for the achievement of corporate objectives.

2.2.2 Quantitative and qualitative characteristics of capacity

In the selection of appropriate personnel and equipment, a number of characteristics and qualities should be taken into account in order to ensure that the capacity is optimally used both technically and economically.

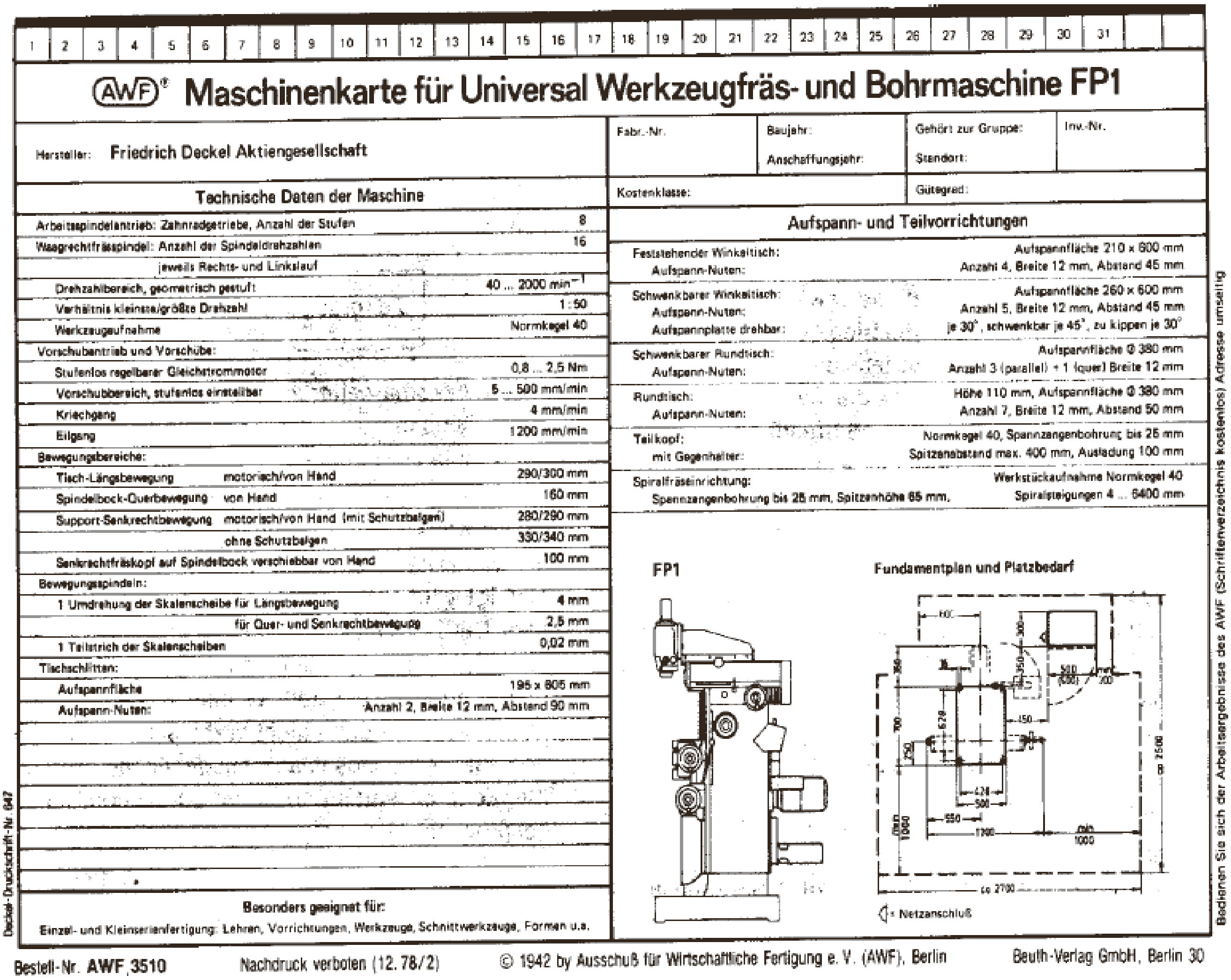
The performance of the equipment for example, plays an important role.

- Performance

The performance of the machines is the interpretation of the technical capacity, which can refer to:

- the geometric capacity, such as center distance of a lathe, clamped bit size of a drill, width of a metal shear and length of a planer.
- the physical capacity, such as speed, feed rate, pressure, installed electric capacity,
- the precision capacity, such as suitability for coarse, medium and fine machining
- the equipment capacity, such as additional equipment, e.g. automatic sorting equipment, lifting equipment

The main performance of a machine can be very clearly seen on an AWF machine card.



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31		

AWF® Maschinenkarte für Universal Werkzeugfräs- und Bohrmaschine FP1

Hersteller: **Friedrich Deckel Aktiengesellschaft**

Fabr.-Nr.

Baujahr:

Anschaffungsjahr:

Gehört zur Gruppe:

Standort:

Inv.-Nr.

Kostenklasse:

Gütegrad:

Technische Daten der Maschine

Arbeitsspindelantrieb: Zahnradgetriebe, Anzahl der Stufen		8
Waagrechtfrässpindel: Anzahl der Spindeldrehzahlen		16
jeweils Rechts- und Linkslauf		
Drehzahlbereich, geometrisch gestuft		40 ... 2000 min⁻¹
Verhältnis kleinste/größte Drehzahl		1:50
Werkzeugaufnahme		Normkegel 40
Vorschubantrieb und Vorschübe:		
Stufenlos regelbarer Gleichstrommotor		0,8 ... 2,5 Nm
Vorschubbereich, stufenlos einstellbar		5 ... 500 mm/min
Kriechgang		4 mm/min
Eilgang		1200 mm/min
Bewegungsbereiche:		
Tisch-Längsbewegung	motorisch/von Hand	290/300 mm
Spindelbock-Querbewegung	von Hand	160 mm
Support-Senkrechtbewegung	motorisch/von Hand (mit Schutzbalgen)	280/290 mm
	ohne Schutzbalgen	330/340 mm
Senkrechtfräskopf auf Spindelbock verschiebbar von Hand		100 mm
Bewegungsspindeln:		
1 Umdrehung der Skalenscheibe für Längsbewegung		4 mm
	für Quer- und Senkrechtbewegung	2,5 mm
1 Teilstrich der Skalenscheiben		0,02 mm
Tischschlitten:		
Aufspannfläche		195 x 805 mm
Aufspann-Nuten:		Anzahl 2, Breite 12 mm, Abstand 90 mm

Besonders geeignet für:

Einzel- und Kleinserienfertigung: Lehren, Vorrichtungen, Werkzeuge, Schnittwerkzeuge, Formen u.a.

Aufspann- und Teilvorrichtungen

Feststehender Winkeltisch:	Aufspannfläche 210 x 600 mm
Aufspann-Nuten:	Anzahl 4, Breite 12 mm, Abstand 45 mm
Schwenkbarer Winkeltisch:	Aufspannfläche 260 x 600 mm
Aufspann-Nuten:	Anzahl 5, Breite 12 mm, Abstand 45 mm
Aufspannplatte drehbar:	je 30°, schwenkbar je 45°, zu kippen je 30°
Schwenkbarer Rundtisch:	Aufspannfläche Ø 380 mm
Aufspann-Nuten:	Anzahl 3 (parallel) + 1 (quer) Breite 12 mm
Rundtisch:	Höhe 110 mm, Aufspannfläche Ø 380 mm
Aufspann-Nuten:	Anzahl 7, Breite 12 mm, Abstand 50 mm
Teilkopf:	Normkegel 40, Spannzangenbohrung bis 25 mm
mit Gegenhalter:	Spitzenabstand max. 400 mm, Ausladung 100 mm
Spiralfräseinrichtung:	Werkstückaufnahme Normkegel 40
Spannzangenbohrung bis 25 mm, Spitzenhöhe 65 mm.	Spiralsteigungen 4 ... 6400 mm

FP1

Fundamentplan und Platzbedarf

◁ = Netzanschluß

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Figure 16: AWF-card machine

The selection of the necessary machine usually occurs during the work flow planning and is dependent on whether it is a single manufacturing process, mass production or automated manufacturing. However, it is important that the existing machines are used wisely.

In the case of a single manufacturing process, the universality of a machine is important, deliberately avoiding high production power. This plays only a minor role because the size of the machine run times compared to the downtimes, set-up and support costs, the construction, transport and shipping, etc. are insignificant.

The universality of the machine tool loses its importance in both the series and mass production. As proven in small and medium series or multi-purpose machines, machines with a lot of capacity are needed for large series production. In large series and mass production, the loading times and the unclamping times of the work pieces significantly determine the level of wage expense. Therefore, it is necessary to ensure that these times are radically reduced. Also, the question of installing the work piece onto the clamping device of the machine and the removal of the work piece after unclamping is important. There are quick clamping devices, lifting devices, and work piece feeders, to reduce these times and therefore, the costs. Machine tools in mass production are often semi automatic or fully automatic machines. Besides the performance of the equipment, the performance of the operating facilities also plays an important role.

The following factors, for example, may play a role:

- type of building
- existing areas
- site conditions such as such as transport links
- the arrangement of jobs

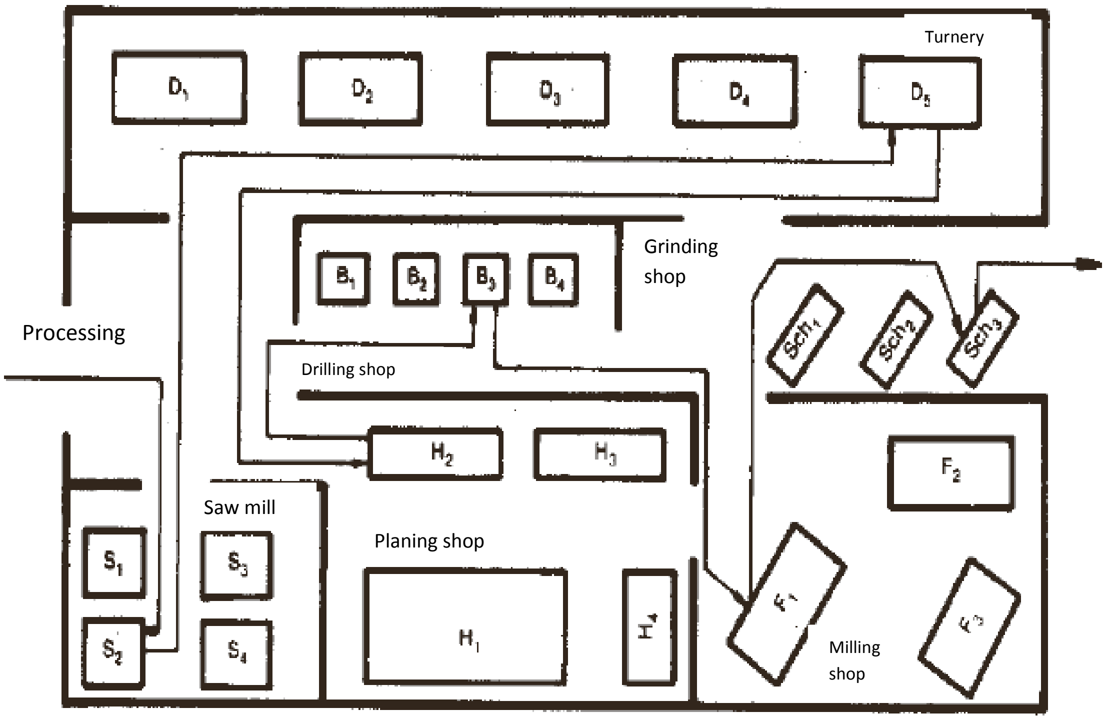

Figure 17: Installation of machinery according to the job shop principle in a production hall.

- Services offered by people

A pre-condition is that a performance can only be rendered by a corresponding range of services by people. But it can only be converted into real performance if he is faced with a job or task.
A worker is suitable for the work to be performed, if services and requirements both quantitatively and qualitatively are met. If the performance offer is greater than the requirements of the work, the performer is unchallenged. This can lead to boredom, dissatisfaction, increased risk of accidents, etc. If the performance offer is lower than the requirements of the work, the performer is overwhelmed. The consequences may be unhappiness, or uncertainty among other things.

The service of man is determined by his skills, his disposition and his drives (fig. 18).

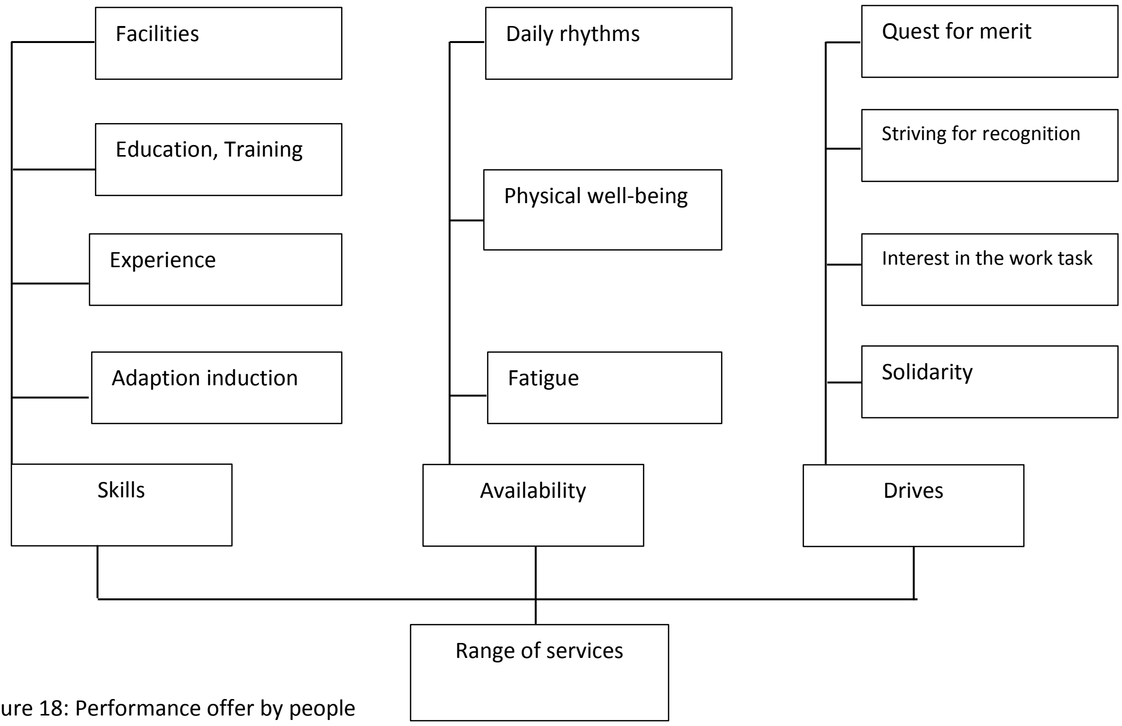

Figure 18: Performance offer by people

Skills arise through:

- Facilities that are granted to anyone, such as color blindness, aptitude for certain things, physical ailments, intelligence, etc.
- Training and practice. The highly trained and experienced person has an advantage over the poorly educated, unskilled, inexperienced person.
- Experience. The experienced person has more skills than a newcomer.
- Adaptation, induction. By longer job tenure, the older employee has adapted to the conditions of operation, he is integrated.

Thus, he has better capabilities and skills than the younger employees. The skills are the maximum capacity that a person can possibly have if he were to be fully exploited

But this is not the case. How should a man bring his full power, if he is not chosen, or if he lacks the drive?

The disposition (availability) is determined by:

- The daily rhythm. The performance management of a person varies with the daily schedule. The daily rhythm which is developed at an early age is linked to the local time and the way of life of the people. This is important for the classification of the working day and for shift change plans.

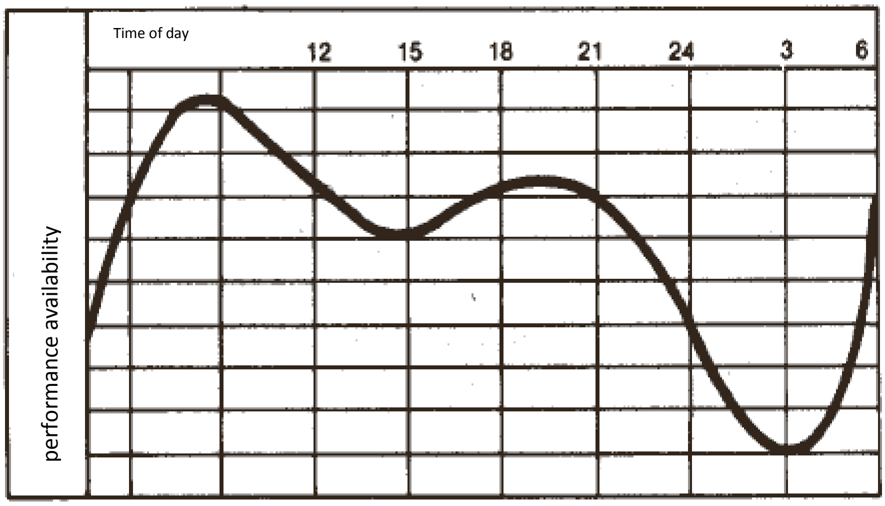

Figure 19: performance availability on a daily basis

- Physical well-being. Malaise, weather conditions, environmental factors, such as noise, dust, etc., can help to ensure that a person is indisposed.

- Fatigue. Fatigue is a loss of performance, which is again compensated by adequate recovery time.

Three types of fatigue can be distinguished (fig. 20):

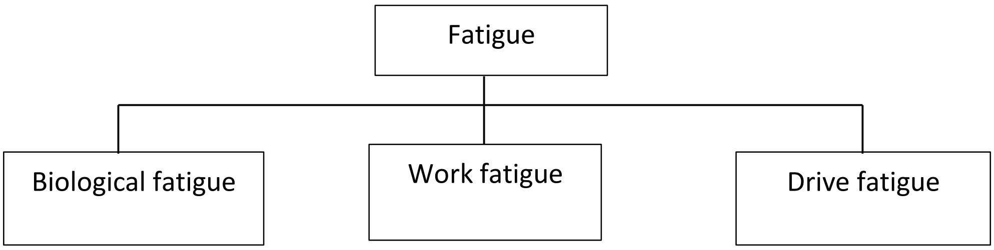

Figure 20: Types of Fatigue

- Biological fatigue
  It sets in whether the person is working or not. The one, who is not working, is also tired in the evening.

- Work fatigue
  It is due to work-related forces and is not harmful to the condition of the body. The work fatigue must be compensated in the shift time, to ensure that performance and health of the working people do not suffer.in the long run.

- Drive fatigue
  If the drive subsides, the performance of a person may drop. Interest weakens, boredom occurs, distraction is greater, and the risk of accident is increased.

The available skills need to be brought into effect through the work task on the internal drives.

Drives can be:

- Quest for merit
  Everyone strives for a good income to satisfy his needs. The company may take this into consideration through performance-related pay, piecework wage, bonuses or performance pay surcharges.

- Striving for recognition
  Every person aspires to be recognized by the company. That can be brought by a manager's praise, by delegation of responsibility and also expressed in other areas of the operation. We all know that after praise, work is done well.

- Interest in the work task
  The work must be equipped with stimulus values for the internal drives. It should be manageable, have visible work progress, the workplace should be neat and clean, clear documentation must be available, the work should be assigned to the available skills.

- Solidarity
  Above all, this is supported by good cooperation of the employees of the company. They should identify themselves with the operation. Solidarity can show if the workers of the company agree to take on overtime in times of scheduling difficulties. The formation of working groups promotes solidarity. One is dependent on the other; the work task can be mastered together with the group.

Summary

The planning of capacity should achieve; that man, machine and operating facilities are optimally combined with each other to ensure the efficiency of production. Tasks include capacity planning, determining capacity requirements, capacity portfolio, the supply and the use of capacity.
Here, the quantitative and qualitative characteristics of the capacity are to be considered, in particular the range of services of the people and the performance of the machines.

2.2.3 Capacity requirements and order backlog

To schedule job capacity for existing orders, it is necessary to determine the capacity requirements. Taken into consideration are how many people and how much resources, and which level of skill or performance capacity, based on the considered period, are required to carry out the tasks.
The capacity requirements must now be reconciled with the existing capacity reserves.

The capacity requirement is compared with the capacity reserves. This results in a **surplus** (the reserve is greater than the need), or a **shortfall** (the reserve is less than the requirements) or a **coverage** for reserve and demand.

Capacity reserves and capacity requirements can be well coordinated.
There are two possibilities.

Adaptation:
Here the reserve and the needs are adapted or even vice versa, the needs are adapted to the reserves. In the first case, the coordination can be done by equipment procurement. In the second case, by reducing the demand, for example by sub-contracting orders. The adaptation is a long-term process.
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Matching:
Here, the demand can be matched by appropriate allocation of existing resources (given reserves). There is talk of a capacity adjustment. The match is a short-term process which is carried out in the context of the control.

2.2.3.1 Determination of operating equipment reserves

For the quantitative determination of operating equipment reserves it must be established which resources, how many and for how long, it is needed during the impending period, for the implementation of the orders. It is important to distinguish between the theoretical and the real operating equipment reserves. The real operating equipment reserves results when the non-usable reserves are deducted from the theoretical reserves.

The theoretical **operating equipment reserves** depend on the working time of the people or of the company. It is calculated from the product of the theoretical operating time of equipment within a shift and the number of shifts per day and the number of working days in a period.
The theoretical operating time of equipment in a shift is then identical to the shift time of people if the operating equipment is continuously used in the shift. Otherwise, it is used during the rest period and to reduce downtimes.

The non-usable operating equipment results from the number of times within the theoretical operating time of a period, in which this equipment is not in use. This includes downtime due to technical errors and interruptions because of personal, material or organization-related disruptions.

As a result of **downtime** (illness, holiday...) of the operating personnel of the equipment, additional downtime may occur: The real operating equipment reserves are still to be provided with a planning factor.

If the calculation of the operating equipment reserves refers to a group of resources, then the respective sizes have to be multiplied by the number of resources.

2.2.3.2 Determination of existing capacity

The number of resources in practice is also known as "the existing capacity".
A distinction is made between the ideal, theoretical or maximum operating equipment reserves, and the real, available or predictable operating equipment reserves.
It is assumed from the ideal reserves, i.e. the theoretical operating time of the equipment. It now depends on the chosen planning period.

In the single-shift operation, the theoretical operating time of the equipment is 8 hours. In two-shift operations, the maximum capacity of the equipment would be 2 x 8 = 16 hours. If there are 21 working days in a month, the theoretical operating time of the equipment in this month would be 21 x 8 = 168 hours in the single-shift operation.

If there are 3 resources available in a department, the maximum capacity would be 3 x 168 = 504 hours. Unfortunately the maximum capacity can not be scheduled.

Factors that reduce the capacity, lead to the actually available and predictable operating time of the equipment, the real reserve.

Such factors can include:

- Illness
  The sickness rate decreases capacity. It may typically be between 4% to 7% for men and 5% to 9% for women.

- Holidays
  Holidays per month result in an annual average between 6% and 8%. In many companies that do not close for company holidays, the most affected months are June, July and August. The reductions must be closely observed especially in these months.

- Machinery breakdowns and other disruptions
  They also reduce the production capacity. But they are very different from operation to operation, from department to department and can be higher, 3% to 8%, through poor organization.

- Scrap and rework
  There are two ways to consider scrap or rework. Either they must be considered during the job planning as a surcharge (they increase the order volume) or as a reduction in the capacity assessment (reducing the existing capacity).As a rule, they are in mass production under the percentage of the series or individual production and can be between 2% to 8%. The more complex

the products, the higher the quality requirements. The more difficult the production, the higher the scrapping and the rework. On the other hand, there are also factors that increase the available capacity.

- Overtime
  Overtime increases the capacity on a short and medium term. However, one should not include it into the permanent capacity calculation. They form a reserve capacity of approximately 2% to 6% and can then be scheduled for disruptions and delays.

- Degree of Time

The **degree of time** can affect the capacity. It is calculated according to the following formula:

$$\textbf{Degree of time} = \frac{specified\ time \cdot 100}{used\ time}$$

As piece workers are usually motivated to earn more (i.e. 100%) the degree of time is usually over 100% (in many companies it is 120% to 130%).

Whether the increase in capacity through the degree of time is actually taken into account in the capacity planning, lies in the decision of the planner. The degree of time can increase the predictable time. However, if it is not taken into account, it then represents a time reserve. Unpredictable disruptions in the production process could then be compensated with this time reserve. (The degree of time will be discussed in the section "Data capture".)

The predictable usage time can be calculated as follows:

Predictable occupancy time =

Number of similar resources

• hours per shift

• shifts per day

• days per planning period

• planning factor (temporal degree)

The planning factor or the temporal efficiency takes into account factors such as equipment malfunction, scrap and rework, missing orders, illness of employee, and so on and is always less than one.

$$\textbf{Planning factor} = \frac{predictable\ operating\ time}{theoretical\ operating\ time}$$

If all these events in a single-shift total 8 hours

the planning factor 78 = 7/8 = 0.88 one hour is allocated for "out of use", then the planning factor would be calculated according to the following formula:

Example 1.1: Example of a planning period of one day's work

theoretical operating equipment reserves: 24 hrs.
real or predictable operating equipment reserves (two shifts à 7 hrs.): 14 hrs.

Planning factor = $\frac{14\,h}{24\,h}$ = 0.583

Results in a planning factor of 0.583.

Example 1.2: Example for the calculation of the degree of capacity

Capacity requirements = 1,458 h
Capacity reserves = 1,674 h

Utilization rate = $\frac{1{,}458\,h}{1{,}674\,h}$ • 100 % = 87.1 %

Example 1.3:

It is the capacity of a machine department (e.g. turning shop) to calculate 20 for the month of April.

The number of production workers is 25 per shift. The company operates in 2 shifts, and each shift is 8 hours. According to the operating calendar, this results in 20 working days.
Taking into account (4%) for illnesses and (8%) for holidays, we arrive at a planning factor of 0.88.

Solution:
The number of hours in the month of April is calculated according to the following approach:

Number of hours	25 • 2 • 8 • 20	= 8,000 hours
Actual capacity	8,000 • 0.88	= 7,040 hours

Should there be orders of 5,800 hours for the month of April in the turning shop and should the average percentage for scrap and rework be 4%, then these results in the desired nominal capacity.

Nominal capacity = 5,800/0.9 = 6,042 hours

Utilization rate = $\frac{nominal\ capacity \bullet 100}{actual\ capacity} = \frac{6{,}042 \bullet 100}{7{,}040}$ = 85.5 %

Thus a planned utilization rate of 85.8% is the result for the turning shop for the month of April.

Example 1.4:

For the cost center, the turning shop, the actual capacity for the next month is 21 working days.

The three machines are used in two shifts, in each shift; the theoretical operating time of the machines is 8 hours. Included in the planned period are three days holiday for operators of a machine and one day for each machine for repair and maintenance due to technical malfunctions.

Solution:
Theoretical operating time = 8 hrs. • 2 shifts • 3 machines • 21 days = 1 008 hrs.

Downtime for the repair and maintenance of one day

Downtime = 1 day • 8 hrs. • 2 shifts • 3 machines = 48 hrs.

Interruption time through 3 days holiday for the operator of a machine

Interruption time = 3 days • 8 hrs. • 2 shifts • 1 machine = 48 h

This results in an actual working operating reserve of

1,008 hrs. - 48 hrs. - 48 hrs. = 912 hrs. or 54 720 min.

Summary

One of the most important tasks of capacity planning is to determine the capacity reserves.
If the capacity reserves are greater than the requirements, it is called an overlap.
If the capacity requirements are greater than the reserves then it is called a shortfall.
If there is an excess of capacity or shortfall, then possibilities must be looked for in order to achieve a capacity covering.
In this context, operational measures such as planning factor, load factor and degree of time plays an important role, as described in the capacity utilization.