Factory Planning Manual
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Situation-Driven Production Facility Planning
Preface

The central purpose of this book is to impart knowledge, skills and practical implementation methods for the planning and operation of adaptable production facilities and factories.

It addresses planning methods and procedures for various types of production facility up to and including entire factories, and is aimed at practicing factory planners and students alike. The book provides facts and demonstrates practical processes using case studies for the purposes of illustration, so that ultimately skills can be acquired that make independent practical implementation and application possible. It is based on up-to-the-minute practical experience and universally applicable knowledge of the planning and technological design of adaptable production facilities (manufacturing and assembly) and factories.

In comparison to existing, thematically-similar reference books, what is innovative about this manual is that it provides the impulse for a more flexible planning approach for the efficient design of adaptable production facilities using responsive, unconventional planning and organizational solutions. The book aims to provide a way of integrating systematic and situation-driven planning methods in a meaningful way. Situation-driven planning is becoming increasingly important to production facilities in these fast-moving times of change, in particular in terms of resource and energy efficiency. Existing technical and organizational course of action in terms of resources (both human and technical) need to be selected for the specific case at hand, and changes (to workshops, products, processes and equipment) need to be managed. Project managers are responsible for assigning subcontracts, coordinating services and combining them in a single project. To this end, the questionnaires and checklists contained in the book and the discussion of potential for change in the case of key planning activities are particularly useful. The book’s appendix expands upon investment appraisal methods, main building and production parameters, supply and disposal systems and the planning and control of information systems.

The book is structured so that it conveys an overview of engineering services for production facility planning.

The book’s scope of application is focused on production facilities for manufacturing parts, assemblies and finished products in the following sectors of industry:

- mechanical engineering and plant construction, electrical and electronic equipment engineering
- process engineering (textiles, clothing, printing and packaging)
- automobile industry and supply industry
- ICT, automation and environmental technology
The main emphasis of the book is on businesses employing make-to-order, small batch and series production for manufacturing processes with differing mechanization and automation solutions and the following types of investment: new, expansion, rationalization and replacement investments.

The manual is intended to be of use to production facility planners, equipment suppliers and operators.

It assumes basic manufacturing and business knowledge and is designed as a self-help guide for:

- interested practitioners,
- students, for acquisition and consolidation of knowledge,
- additional and further education for specialists,
- specialists and managers from industry, services and business, primarily in the fields of production engineering, industrial engineering, production management, construction, architecture and logistics.

This manual is a practical addition to existing reference and text books, and in particular “Fabrikplanung und Fabrikbetrieb” (Factory Planning and Factory Operation) published by Springer (Schenk & Wirth 2004) and “Montage in den industriellen Produktionsstätten” (Assembly in Industrial Production Facilities) (Lotter & Wiendahl 2006), as well as the teaching materials of various educational and training establishments. Papers on Factory Project Design (Helbing 2007), “Facility Design and Engineering” (Hanna & Konz 2004) and “Changeable Manufacturing” (Wiendahl 2007) are also included. To aid understanding, these books, and in particular “Fabrikplanung und Fabrikbetrieb” (Factory Planning and Factory Operation), are recommended to help readers acquire a basic knowledge of the subject.

Both within and beyond the European Union’s borders, manufacturing industry is subject to a multitude of country-specific standards, directives and regulations. In order to guarantee the uniformity, transparency and comprehensibility of the examples, we have referred primarily to EU standards (EN, ISO and DIN), VDI/VDE guidelines and German domestic regulations. Country-specific stipulations must therefore be accommodated and adapted separately.

The authors would particularly like to thank the staff of the Institute of Industrial Management and Factory Systems, department of Factory Planning and Factory Operation and of the Fraunhofer Institute for Factory Operation and Automation (IFF), as well as the Institute of Logistics and Material Handling Systems (ILM), department of Logistics Systems and the companies and institutions for their kind cooperation in supplying academic papers.

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Magdeburg and Chemnitz, May 2009
Michael Schenk Siegfried Wirth Egon Müller
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List of abbreviations

0 + 5 + X model
Planning model
0 = Project definition (01 to 05)
5 = Project development (5.1 to 5.5)
x = Project implementation (x6 to x10)

2D
2 dimensional

3D
3 dimensional

ABC analysis
NB: does not stand for activity based costing (process costs), but for a quantity and value analysis for the categorization of any given item in the 3 groups A, B and C. Commonly used for procured goods, customers and warehouse stock.

ABC-XYZ characteristic
Categorization of any given object (e.g. customers, orders, parts, assemblies, replacement parts, products) into 3 groups according to quantity and value (A, B, C) and demand behavior (X, Y, Z) criteria. This produces a 9 field matrix of possible combinations (e.g. group AX) for which generic strategies can be derived.

AC
Alternating current

AGBG
German Act Governing General Terms and Conditions (Gesetz zur Regelung des Rechts der Allgemeinen Geschäftsbedingungen)

AMM
Auxiliary manufacturing material

APS
Advanced Planning System

AR
Augmented Reality

ArbStättV
German regulations governing the workplace (Arbeitsstättenverordnung or Workplace Ordinance)

ASR
German workplace guidelines (Arbeitsstättenrichtlinien)

AWSA
Assembly workstation area

BAT
Biological Tolerance values (Biologischer Arbeitsstoff-Toleranz-Wert)

BGB
German Civil Code (Bürgerliches Gesetzbuch)

BMV
German Federal Ministry of Transport (Bundesministerium für Verkehr)

BSC
Balanced Scorecard

CAD
Computer Aided Design

CAFM
Computer Aided Facility Management system

CAP, CAPP
Computer Aided Planning systems, Computer Aided Process Planning system

CIM
Computer Integrated Manufacturing

CL
Client

CNC
Computerized Numerical Control

CRM
Customer Relationship Management systems

CO
Contractor
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>CONWIP</td>
<td>Constant Work in Process</td>
</tr>
<tr>
<td>CS</td>
<td>Components and parts suppliers</td>
</tr>
<tr>
<td>DBS</td>
<td>Database System</td>
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<tr>
<td>DC</td>
<td>Direct current</td>
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<tr>
<td>DIN</td>
<td>German Institute for Standardization (Deutsches Institut für Normung)</td>
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<tr>
<td>DNC</td>
<td>Distributed (or Direct) Numerical Control</td>
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<tr>
<td>EKA</td>
<td>Exposure Equivalent for Carcinogenic Substances (Expositionsäquivalent für krebserzeugende Arbeitsstoffe)</td>
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<tr>
<td>ERP</td>
<td>Enterprise Resource Planning system</td>
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<tr>
<td>FAQ</td>
<td>Frequently asked questions</td>
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<tr>
<td>FEM</td>
<td>European Federation of Materials Handling (Federation Européenne de la Manutention)</td>
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<td>FMC</td>
<td>Flexible manufacturing cell</td>
</tr>
<tr>
<td>FTT</td>
<td>(Jigs &amp; Fixtures, tools and testing equipment</td>
</tr>
<tr>
<td>GeWo</td>
<td>German Trade Commerce and Industry Regulation Act (Gewerbeordnung)</td>
</tr>
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<td>GI</td>
<td>Goods inwards</td>
</tr>
<tr>
<td>GO</td>
<td>Goods outwards</td>
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<tr>
<td>HGB</td>
<td>German Commercial Code (Handelsgesetzbuch)</td>
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<tr>
<td>ICP</td>
<td>In-cyclical parallelism</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<tr>
<td>JIS</td>
<td>Just in sequence</td>
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<td>JIT</td>
<td>Just in time</td>
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<tr>
<td>LAN</td>
<td>Local Area Network</td>
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<td>LTUs</td>
<td>Conveyor</td>
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<td>MAP</td>
<td>Manufacturing Automation Protocol</td>
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<tr>
<td>MDA</td>
<td>Machine data acquisition</td>
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<tr>
<td>MEK</td>
<td>Maximum Emissions Concentration (Maximale Emissions-Konzentration)</td>
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<tr>
<td>MES</td>
<td>Manufacturing Execution Systems</td>
</tr>
<tr>
<td>MIK</td>
<td>Maximum Immissions Concentration (Maximale Immissions-Konzentration)</td>
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<tr>
<td>MMO</td>
<td>Multiple machine operation</td>
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<td>MSS</td>
<td>Management Support System</td>
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<tr>
<td>NC</td>
<td>Numerical control</td>
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<tr>
<td>NS</td>
<td>Number of shifts</td>
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<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<tr>
<td>OP</td>
<td>Operation</td>
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<tr>
<td>OPC</td>
<td>OLE (object linking and embedding) for Process Control</td>
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<tr>
<td>OSACA</td>
<td>Open system architecture for controls within automation systems</td>
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<tr>
<td>OSI</td>
<td>Open System Interconnection</td>
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</table>
PC  Processing center
PCC  Production control center
PDA  Production data acquisition
PDAs  Personal Digital Assistants
PDCA cycle  Deming’s Plan – Do – Check – Act cycle
PDM  Production data management
PerP  Performance program
PLC  Programmable logic controller
PMS  Project Management Systems
PP  Production program
QFD  Quality Function Deployment
QMS  Quality Management Systems
R&D  Research and development
R&D Tools  Research and development tools
RefP  Reference period
RP  Replacement parts
SS  System supplier
STEP  Standard for the exchange of product model data
SUB  Subcontractor
SWOT  Strengths, Weaknesses, Opportunities and Threats
TBS  Technical building systems
TCP/IP  Transmission Control Protocol/Internet Protocol
TGL  German technical quality and supply standards (Technische Güte- und Lieferbedingungen)
THS  Transport, handling, storage
TOP  Technical and Office Protocol
3-phase AC  Three-phase alternating current
TPT  Throughput time
TR/TG  Technical rules / Technical guidelines
TRep  Type representatives
TRK  Technical reference concentration (Technische Richtkonzentration)
TÜV  German Technical Inspection Association (Technischer Überwachungsverein)
UDM  Universal lathe
UVV  German accident prevention regulations (Unfallverhütungsvorschriften)
VBG  German employers’ liability insurance association (Verwaltungs-Berufsgenossenschaft)
VDI  Association of German Engineers (Verein Deutscher Ingenieure)
VDE  German Association for Electrical, Electronic & Information Technologies (Verband der Elektrotechnik Elektronik Informationstechnik)
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>WHG</td>
<td>German Federal Water Act (Wasserhaushaltsgesetz)</td>
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<tr>
<td>WLAN</td>
<td>Wireless Local Area Network</td>
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<tr>
<td>WMS</td>
<td>Workflow management system</td>
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<tr>
<td>WP</td>
<td>Wearing parts</td>
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<td>WTR</td>
<td>Working time requirement</td>
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1 Introduction

1.1 Business Enterprises, Workshops and Factories

a) Business enterprises are commercial operations that earn profits by charging prices that exceed their costs. A business enterprise develops products and provides services.

Manufacturing enterprises manufacture products. Procurement, manufacturing and sales and distribution departments together with the necessary production facilities and factories are needed to develop products.

Production facilities, workshops and factories are basic tools used by businesses to add value. Figure 1.1 illustrates the production facility’s position in the enterprise environment.

![Figure 1.1 Production facilities as part of an enterprise (Schmigalla 1995)](image)

Manufacturing enterprises are subject to constant changes that are influenced by innovation, policy, the environment and the economy. Changes demand flexibility and adaptability on the part of manufacturing enterprises as well as flexible planning. Figure 1.2 shows factors that have an influence on change.
Maximization of profitability and, in addition, flexibility, adaptability and attractiveness will continue to be corporate objectives in the future (fig. 1.3).

Flexibility and adaptability apply both to the enterprise - including its production facilities - and the processes for planning efficient organizational solutions.
Finally, the corporate units responsible for production scheduling and execution in particular must ensure through planning that the technical order process is efficient for the production facility’s operator (cf. fig. 1.4) (Spur 1994).

**Fig. 1.4 Technical order process**

b) *Workshops* – the technical and organizational part and economic unit of a business enterprise (company). They have the job of producing and commercializing goods and services to satisfy customer demands. They can be broken down into structural and functional units as shown below.

**Structural units:**
- division, department (production, management)
  - section
  - group
  - workstation

These are technical and organizational elements of a factory, which are (hierarchically) structured according to management and leadership principles.

- Cost center
  This is a part of a plant to which costs incurred are allocated and recorded separately.

**Functional units:**
parts manufacture, assembly and logistics (transport, handling and storage)
Figure 1.5 shows a basic model of a workshop with the task assigned, input and output variables, the scope of work of both human resources and equipment, plus the working environment and workflow.

![Production Program Diagram](image)

**Fig. 1.5** The basic workshop model (Warnecke 1992)

c) *Factories* - are industrial operations that pursue profit-making and cooperative goals. They have organizational areas for which various processes (functions) and facilities must be planned and carried out. Production and operating facilities and workstations are all constituent parts of a factory. Figure 1.6 illustrates the various organizational areas for personnel/workforce, equipment and technical systems in a factory. (See also chapter 6).

![Organizational Areas Diagram](image)

**Fig. 1.6** The organizational areas and facilities of a manufacturing site
General elements of a factory/production facility include (cf. also ch. 6):

**Personnel/workforce**
- number, gender
- qualifications, skills

**Machinery and equipment:**
- manufacturing and assembly equipment: machinery/workstation including fixtures/auxiliary equipment and tools
- logistics facilities: transport, handling, storage and order picking facilities including auxiliary warehouse and transport equipment
- quality assurance equipment: measuring and testing equipment, jigs and fixtures/auxiliary equipment
- control, information and communication systems
- safety, emissions and interference suppression systems
- supply and disposal systems for utilities, power, raw materials and auxiliary materials; waste and residual materials

**Technical systems** (in conjunction with their structures):
- structural equipment: supporting structures, foundations, pillars, beams, roof structure
- envelope: facades, roofs including windows, doors, gates
- interior: flooring, ceilings, dividing walls, openings
- building systems: heating, ventilation, air conditioning, sanitary facilities
- supply and disposal systems for utilities: power, gas, water (drinking and industrial water), electricity, raw materials, auxiliary, waste and residual materials

**Operating materials:**
- liquid materials (fluids, media): water, oils and greases, coolants, acids and bases, solvents, cleaners, polishing materials and abrasives, fuels, paints, biological materials
- gaseous materials: technical gases, technical fuel gases, gas mixtures, steam
- solid materials: fuel, paper and cardboard, glass, administrative equipment

Compatibility, deconfigurability and reconfigurability, mobility, modularity and universality all characterize adaptable equipment, plant and production systems (Wiendahl 2005, Spur 2007). Figure 1.7 illustrates common change scenarios that give rise to changes in personnel and technical resources.

Different types of factories (factory types) can be categorized according to their different characteristics. Figure 1.8 lists the characteristics and various attributes, which are mainly based on technical/organizational and economic aspects. They can be combined to produce a multitude of factory types with their various production facilities. Figure 1.8 shows an example of a factory type/production facility.
Fig. 1.7 Selected change scenarios (Hildebrand 2005, p. 19)

Fig. 1.8 Morphology for determining factory types – extract (Schenk & Wirth 2004, p. 18) (cf. 5.2.1.2)
Note: factories and production facilities are unique entities. Every factory is different in terms of its human resources, products, processes, systems, function, dimensions, structure, layout, profitability and corporate philosophy. The ability of production facilities to adapt is becoming a top priority for modern enterprises and is a perpetual task for management.

1.2 Product, Processes and Plants

In an enterprise, the job of a production facility is to perform competitively on the market by producing (material) goods as products. The interrelationship between the product, processes and plant thus deserves attention (cf. fig. 1.9).

![Fig. 1.9 Relationship structure between product, production process and plant](image)

Note: the product desired by the customer determines the process (in units of individuals, equipment and organization) and the process determines the plant (equipment, facilities and items) that individuals operate, control and supervise.

Changing one component results in changes to other components. This applies to production facilities as well as to an entire factory, as in figure 1.10.
Customer requirement (1) – a concept devised by a customer or group of customers that is fulfilled by competitive products in the form of physical goods and services with high customer value.

Customer order – order placed by the customer for physical goods and services.

Product (2) – The outcome of operating processes that serves to satisfy customer requirements. (Product, assembly, component, repetitive parts, raw materials)

Value-added process (3) – The set of all commercial activities that are carried out to meet a customer requirement; it is implemented by value-added units in the value-added chain (research, development, procurement, operations scheduling, manufacturing, assembly, distribution).

Production process (4) – All processes involved in the production of goods and services in a combination of human resources (workforce), technology (object being worked upon and equipment) and organization. It encompasses design engineering/development, purchasing, production planning and control, machining and processing and THS, assembly and THS, and distribution, sales and service.

Manufacturing plant (5) – The production of individual parts by means of machining and processing equipment and systems, including transport, handling and storage equipment, with purchasing, production planning and control (and limited design engineering and sales).

Assembly system (6) – Creation of component assemblies (system components, products) using joining and assembly equipment (systems) including transport,
handling and storage equipment, with purchasing, production planning and control (and limited design engineering and sales).

*Production line (7)* – The integration of machinery and plants for different technological manufacturing (manufacturing lines) and assembly (assembly lines) processes, including transport, handling and storage equipment, with design engineering, purchasing, production planning and control, distribution and sales.

*Building complex (8)* – A building with its geometric and load parameters including technical building systems to house production facilities or parts thereof. The building is the operational repository of technological processes and technical systems, the site where goods are produced, and a key element adapted to the environment with infrastructure connecting to the site. Technical building systems (TBS) include building, supply and disposal systems, e.g. water, waste water, gas, heating, ventilation, power, IT, safety and automated systems.

*Factory complexes (9)* – Buildings with production lines and connections to infrastructure.

*Infrastructure (10)* – The site and factory’s supply and disposal systems (power, water, gas, transport routes, etc.) installed in the location.

### 1.3 Structure of Production Facilities

The structure (Wirth 2000) is subdivided into:

a) hierarchical organization levels (fig. 1.11)

This corresponds to the structure of the workshop from the division through the section (department), to the group and workstation for manufacturing and assembly operations.

**Note:** the manufacturing workstation is the smallest unit. A manufacturing group consists of several manufacturing workstations, a manufacturing section consists of manufacturing workstations and manufacturing workstation groups, and so on. The interfaces between them are formed by storage areas connected by flow systems.
b) Peripheral areas  (fig. 1.12)

These are based on the main parts manufacturing and assembly processes. Varying degrees of interconnection (direct or indirect) with the product being manufactured (production program) yields three peripheral areas.

*First periphery* - Systems that are *directly* connected to the product and thus directly connected to the main process (connected to the object being worked on), e.g. quality control, warehouse, control.

*Second periphery* - Systems that are *not* connected to the product but directly connected to the main process systems (connected to equipment), e.g. maintenance, auxiliary materials

*Third periphery* - Systems that are *independent* of the main process and its systems. These include social and management facilities (dependent on the workforce), e.g. sanitary facilities, administrative services.

**Note:** planning always proceeds from the center (main process) and then in sequence from the first periphery to the second and third.
c) Functional Organization (cf. fig. 1.13)

In a production facility different processes occur that need to be planned for different process elements. Process elements might be material, information and energy. Since process functions are also called flow functions, they are known as material, information and energy flows. Thus the flow object is the material, information or energy as well as their related systems and facilities (cf. ch. 6.2 and 6.3.6.4).
### Material flow systems

- **Production/material flow systems**
  - Parts (unfinished/finished parts)
  - Units (assemblies)
  - Finished products
  - Purchase parts and standard parts
  - THS equipment

- **FTT flow systems**
  - Jigs & fixtures
  - Tools
  - Testing equipment

- **Supply and disposal/building flow systems**
  - Auxiliary manufacturing materials
  - Waste (turnings & chips, parts scrap)
  - Air (fresh air/exhaust air)
  - Water (drinking and fresh water/wastewater)

### Energy flow systems

- Electrical energy (power units, heating, IT)
- Compressed air / hydraulic system
- Technical gases
- Indoor air (air conditioning)
- Steam, hot water (heating)

### Information flow systems

- Production scheduling information flow systems
  - Information processing in the management units (organization, planning/controlling)
  - Procurement/processing of external management information
  - Information processing in design engineering and operations scheduling

- Production execution information flow systems
  - Information processing in production planning and control
  - Information processing to control machinery
  - Information processing to control and monitor processes
  - Information processing to capture operating data

---

**Fig. 1.13** Material, energy and information flow systems

**Material flow:** within material flow, the flow of unfinished parts through to the finished product takes top priority in terms of planning. The Sankey diagram in figure 1.14 shows the product flow interrelationships on a machinery production line. The material flow also includes operating materials such as fluids (liquids, powders) and wastes.

![Sankey diagram of material flow](image)

**Fig. 1.14** Product flow on a machinery production line (Sankey diagram)
Energy flow: every process requires energy to fulfill its function. The forms of energy can vary. Therefore power equipment for electricity (DC, AC and three-phase), liquid (water, wastewater, oil) and gaseous media (steam, technical gases, compressed air) can all be required.

Information flow: information (data) with the pertinent IT equipment (e.g. computers, memory, cable) is needed to prepare for and execute production. This applies to the planning, scheduling, coordination, communication and technical control of plants.

Other additional flows include:

Personnel (work) flow: every process takes place under the supervision and with the interaction of workers. The workflow stipulates the allocation of labor in the process flow.

Capital and cost (value) flow: the value-added process is assessed using costs. The costs and value of a product change with the manufacturing process. The value of a product increases and the value of the equipment (plant) decreases during the production process (cf. ch. 6.2).

Note: material, energy, information, personnel and capital (value) flows, plus their systems and equipment and their connection to one another must be planned and implemented for every production facility. First of all, product and material flows must be planned with the workflow followed by the information, energy and value flows. Changes in a flow have a sustained effect on the other flows and their equipment. Flexible processes and systems/equipment improve adaptability and thus competitiveness. Every flow must be organized to be resource and - in particular - energy efficient.

1.4 Demands Placed on the Production Facility

The organization of production facilities relates to both “physical products” and to “services” and consequently represents a “hybrid product” for the customer whereby physical products and services blend with one another. The functions that are associated with this represent a package composed of a tailored combination of physical products and services geared towards the customer (Bundnek 2007).

In relation to physical products, when it comes to selling consumer and industrial goods, the marketing of services as an additional area of business is ever increasing, and offers strong potential for engineering services.

a) Physical products result from the specified product, process, system, human resource and administration-related requirements and their technical solutions.
Table 1.1 Demands placed on the production facility

<table>
<thead>
<tr>
<th>Product and production process-related requirements</th>
<th>Human resource-related requirements</th>
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<tbody>
<tr>
<td>Product technology</td>
<td>Social and sanitary protection</td>
</tr>
<tr>
<td>Production technology</td>
<td>Occupational safety, workspace climate</td>
</tr>
<tr>
<td>Security of supply</td>
<td>Air conditioning</td>
</tr>
<tr>
<td>Security of disposal</td>
<td>Occupational ergonomics/usability</td>
</tr>
<tr>
<td>Climate</td>
<td>Color scheme</td>
</tr>
<tr>
<td>Flow reliability</td>
<td>Minimal noise, immission control</td>
</tr>
<tr>
<td>Connections/interfaces</td>
<td>Illumination/daylight/lighting</td>
</tr>
<tr>
<td>Flexibility/adaptability</td>
<td>Collision protection, protection from harmful interference</td>
</tr>
<tr>
<td></td>
<td>Level of protection, protection against fire</td>
</tr>
<tr>
<td></td>
<td>Controllability and manageability</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant-related requirements</th>
<th>Management-related requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility and freedom of movement</td>
<td>Administrative tasks and equipment</td>
</tr>
<tr>
<td>Access, openings</td>
<td>Functionality of management</td>
</tr>
<tr>
<td>Universal use</td>
<td>Communication, IT equipment (EDP)</td>
</tr>
<tr>
<td>Upgradability</td>
<td>Office space</td>
</tr>
<tr>
<td>Configurability, modularity</td>
<td></td>
</tr>
<tr>
<td>Utilization of space and spatial geometry</td>
<td></td>
</tr>
</tbody>
</table>

These requirements, which are based on Helbing (2007), should be reviewed on a case by case basis.

b) Services result from the environment of the physical goods produced by the consumer and industrial goods industry. They rank among industry-oriented, product-related services. Table 1.2 summarizes production-related services for the fields of mechanical engineering and plant construction for the entire product life cycle from planning, commissioning and operation through to maintenance, reuse and disposal (Naumann 2008).

Table 1.2 Production-related services

<table>
<thead>
<tr>
<th>Planning</th>
<th>Planning tasks</th>
<th>Commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyses and Studies</td>
<td>Raw materials inspections</td>
<td>x</td>
</tr>
<tr>
<td>Technical testing, analysis</td>
<td>Technical testing, analysis</td>
<td>x</td>
</tr>
<tr>
<td>Troubleshooting/needs assessment</td>
<td>Troubleshooting/needs assessment</td>
<td>x</td>
</tr>
<tr>
<td>Site inspections</td>
<td>Site inspections</td>
<td>x</td>
</tr>
<tr>
<td>Market research / market studies</td>
<td>Market research / market studies</td>
<td></td>
</tr>
<tr>
<td>Value analyses</td>
<td>Value analyses</td>
<td></td>
</tr>
<tr>
<td>Profitability analyses / return on capital studies</td>
<td>Profitability analyses / return on capital studies</td>
<td>x</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planning</th>
<th>Planning tasks</th>
<th>Commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyses and Studies</td>
<td>Technical testing, analysis</td>
<td>x</td>
</tr>
<tr>
<td>Troubleshooting/needs assessment</td>
<td>Troubleshooting/needs assessment</td>
<td>x</td>
</tr>
<tr>
<td>Site inspections</td>
<td>Site inspections</td>
<td>x</td>
</tr>
<tr>
<td>Market research / market studies</td>
<td>Market research / market studies</td>
<td></td>
</tr>
<tr>
<td>Value analyses</td>
<td>Value analyses</td>
<td></td>
</tr>
<tr>
<td>Profitability analyses / return on capital studies</td>
<td>Profitability analyses / return on capital studies</td>
<td>x</td>
</tr>
<tr>
<td>Feasibility studies</td>
<td>Processing of approval procedures</td>
<td>Patent and license agreements</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Organizational analysis</td>
<td>Loan brokerage</td>
<td>Expertise agreements</td>
</tr>
<tr>
<td>Environmental impact investigations</td>
<td>Financing</td>
<td>Management contracts</td>
</tr>
<tr>
<td>Pre-competitive product development (industrial research and development)</td>
<td>x Cost estimates</td>
<td>x Rental machines to bridge the gap until delivery</td>
</tr>
<tr>
<td>Process analyses</td>
<td>x Cost estimation support</td>
<td>Machine insurance</td>
</tr>
<tr>
<td>Time studies, time management</td>
<td>x Development of technology</td>
<td>Training courses</td>
</tr>
<tr>
<td>Risk analysis, securing of CE mark</td>
<td>x Material flow planning, process design (simulation)</td>
<td>x User/operator training</td>
</tr>
<tr>
<td>Consulting</td>
<td>Planning of technological concepts</td>
<td>Computer-based training</td>
</tr>
<tr>
<td>Technology consulting</td>
<td>x Development of factory logistics concepts</td>
<td>Online user training</td>
</tr>
<tr>
<td>Technical consulting</td>
<td>x Product development (general framework specifications and requirements specification)</td>
<td>Technology training</td>
</tr>
<tr>
<td>Operating resources consulting</td>
<td>Technical planning</td>
<td>Maintenance training</td>
</tr>
<tr>
<td>Environmental consulting</td>
<td>Construction</td>
<td></td>
</tr>
<tr>
<td>Legal advice</td>
<td>Drive dimensioning project planning</td>
<td>Transport</td>
</tr>
<tr>
<td>Advice relating to tools</td>
<td>Factory, layout planning</td>
<td>Transport organization</td>
</tr>
<tr>
<td>Organizational consulting</td>
<td>Ergonomic workstation design, industrial engineering (data calculation)</td>
<td>Transport insurance</td>
</tr>
<tr>
<td>Financing advice (R&amp;D funds)</td>
<td>x Control/safety concepts</td>
<td>Ramp-up management</td>
</tr>
<tr>
<td>Provision of advice and support in the design of a quality and environmental management system</td>
<td>x Concepts relating to the safety of personnel</td>
<td>Building works / facilities</td>
</tr>
<tr>
<td>Manufacturing in the strictest sense</td>
<td>Simulation of workpiece throughput (process suitability of the machines)</td>
<td>Assembly</td>
</tr>
<tr>
<td>Sample production</td>
<td>x Tests using virtual reality</td>
<td>Adaptation to existing plant (updating)</td>
</tr>
<tr>
<td>Manufacturing to bridge the gap until delivery</td>
<td>x 3D ergonomic simulation</td>
<td>Production scheduling</td>
</tr>
<tr>
<td>Assembly</td>
<td>Software planning</td>
<td>Commissioning</td>
</tr>
<tr>
<td>Development of CNC/PLC and MDA/PDA program</td>
<td>x Replacement/wearing parts (RP/WP)</td>
<td>Test pieces</td>
</tr>
<tr>
<td>Development of measuring station program</td>
<td>Hotline</td>
<td>Troubleshooting</td>
</tr>
<tr>
<td>Help for machinery operation</td>
<td>Supply with own RP/WP</td>
<td>Process security</td>
</tr>
<tr>
<td>On-site production support</td>
<td>x Ordering of original RP/WP</td>
<td>Production of pre-launch and pilot batches</td>
</tr>
<tr>
<td>Remote machinery and plant operation consulting</td>
<td>x Replacement part service (24h)</td>
<td>Introduction of change management</td>
</tr>
<tr>
<td>Production-related training courses</td>
<td>Marketing of external RP/WP</td>
<td>Plant improvement</td>
</tr>
<tr>
<td>FAQs (answers to frequently asked questions)</td>
<td>Consignment (buffer/supply) stock – RP/WP</td>
<td>Updating/modernization of machinery</td>
</tr>
<tr>
<td>Hotline/teleservice</td>
<td>x Replacement part management (documentation, logistics, stock control, statistics, determination of requirements)</td>
<td>Processing technical inquiries</td>
</tr>
<tr>
<td>Online self-service (Helpware); Online manuals</td>
<td>EDP services</td>
<td>Troubleshooting</td>
</tr>
<tr>
<td>Animated multimedia documentation</td>
<td>Downloads of software (e.g. simulation/diagnosis software, maintenance tools)</td>
<td>Machinery and process diagnosis</td>
</tr>
<tr>
<td>Tooling (tool making)</td>
<td>Updating/Upgrading</td>
<td>Investigating idle time</td>
</tr>
<tr>
<td>NC parts programming</td>
<td>x Adaptation programming / modification</td>
<td>Project-related technology /process consulting and op-</td>
</tr>
</tbody>
</table>
## Introduction

### Data management
- MDA: Machine, (manufacturing, process) data acquisition, storage, processing and evaluation
  - x Receipt of claims and complaints
  - x Investigating energy savings
- PDA: Parts (product) data acquisition, storage, processing and evaluation (quality inspection, parts traceability)
  - x Data management
  - x Safety, risk and hazard analysis
- ODA: Order (operating) data acquisition, storage, processing and evaluation (production statistician)
  - x Provision of product documentation (manuals)
  - x Machine relocation

### Maintenance
- Recording of complaints customer suggestions/problems
  - x Reuse
- Cleaning of machinery
  - x Reference customer visit
  - x Development of de-integration plans
- Preventive maintenance
  - x User groups (customer exchange of experience)
  - x Acceptance of returned machinery, equipment, used parts
- Surveying
  - x Non order-related training
  - Automatic reuse
- Remote diagnosis/teleservice (mobile maintenance)
  - x Product-related symposia
  - Trade in used machinery
- Breakdown management
  - x Publication of interesting findings
  - Sale of used parts, equipment and machinery
- Repair/servicing
  - x Newsletter (e.g. case studies, tips, news)
  - Brokerage of used machinery
- Servicing
  - x Customer magazine
  - Reconditioning
- General overhauling
  - x Disassembly
- Manufacturer-independent repair of competitor’s products
  - Large-scale inspection and plant refurbishment
  - Revamping
  - Conversion / refitting
  - Overhauling, retrofitting
  - see also system development.

### Disposal
- Withdrawal from service
- Organization of decommissioning process
- Scrapping of old equipment
- Recycling of materials
- Waste management

### Note:
Production facility design integrates physical products with services and represents a “hybrid product” for the customer.
2 Systematic and Situation-Driven Planning Methods

2.1 Planning Project

Planning production facilities means envisioning production in advance. This necessitates using instruments that efficiently design the planning process. A systematic, methodical approach is influenced by situation-driven decisions. It serves the development of a (planning) project through internal and/or external planning activities.

Project design denotes a creative design activity that utilizes preprepared technical building blocks/modules (components, assemblies, individual systems, etc.) and organizational solutions to design, dimension, structure and configure a user friendly technical unit (device, machine, plant, building, production facility, etc.). The result is a planning project. Figure 2.1 shows the features of a planning project.

A planning project involves the development of and is a prerequisite for the construction of production facilities in preliminary and execution planning.

---

**Technical Disciplines Involved**

The following professional disciplines - among others – that are part of a planning project must be managed during the planning and implementation process:
Table 2.1 Production-related technical disciplines

<table>
<thead>
<tr>
<th>Role</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project engineer and project manager</td>
<td>Production facilities and factory design</td>
</tr>
<tr>
<td>Architects</td>
<td>Building design</td>
</tr>
<tr>
<td>Specialist engineers</td>
<td>Structural analysis, heating, sanitary facilities, electrical systems, etc.</td>
</tr>
<tr>
<td>Production engineers</td>
<td>Machinery, equipment, jigs and fixtures, tools</td>
</tr>
<tr>
<td>Logisticians</td>
<td>Transport, handling, storage</td>
</tr>
<tr>
<td>IT engineers</td>
<td>Planning, control and automated systems</td>
</tr>
<tr>
<td>Design engineers</td>
<td>Product specifications</td>
</tr>
<tr>
<td>Business managers</td>
<td>Target costs, operating efficiency, budget</td>
</tr>
<tr>
<td>Ergonomists</td>
<td>Working time and remuneration systems, ergonomics</td>
</tr>
<tr>
<td>Psychologists</td>
<td>Conflict management, motivational techniques</td>
</tr>
<tr>
<td>Suppliers</td>
<td>Trades, technical building systems (TBS)</td>
</tr>
<tr>
<td>Authorities</td>
<td>Permits, approvals</td>
</tr>
<tr>
<td>Experts</td>
<td>Reports and surveys</td>
</tr>
<tr>
<td>Attorneys</td>
<td>Contracts</td>
</tr>
</tbody>
</table>

The point of departure for all planning is the customer order as the basis for verification of performance agreed upon by the client and the contractor in the form of technical and requirements specifications (in accordance with DIN 69905). This results in the planning and project order that includes the planning basis for products (production programs), quantities, times, production processes, resources (workforce, plant, floor space, personnel), investments (costs, turnover and profit) and legal aspects.

2.2 Planning Process and Procedural Models

A planning project can be developed systematically and/or situation-driven on the basis of various planning process and procedural model views.

a) Systematic Planning Processes

(1) Production facility and factory life cycle design planning phases and stages (fig. 2.2).

Planning activities span a production facility’s entire life cycle from development/planning through setup, execution and operation to phase-out. Three planning stages are always implemented within the individual phases.

The following reflections concentrate on “planning/project design” (the planning project) and setup or “execution planning” (the implementation project).
Fig. 2.2 Production facility and factory life cycle design planning phases and stages (Schenk, Wirth 2004)

(2) Views of the planning process based on planning levels, stages and steps (fig. 2.3)

Fig. 2.3 Views of the planning processes