Factory Planning Manual

Michael Schenk · Siegfried Wirth · Egon Müller

Factory Planning Manual

Situation-Driven Production Facility Planning

Springer

Prof. Michael Schenk
Otto von Guericke University, Magdeburg
Institute of Logistics and
Material Handling Systems
Chair of Logistics Systems
Universitätsplatz 2
D-39106 Magdeburg
Director of the Fraunhofer Institute for
Factory Operation and Automation IFF
Sandtorstr. 22
D-39106 Magdeburg
michael.schenk@iff.fraunhofer.de

Prof. Egon Müller
Chemnitz University of Technology
Institute of Industrial Management
and Factory Systems
Professorship of Factory Planning
and Factory Operation
D-09107 Chemnitz
egon.mueller@mb.tu-chemnitz.de

Prof. Siegfried Wirth
Chemnitz University of Technology
Institute of Industrial Management
and Factory Systems
IREGIA e.V.
D-09107 Chemnitz
s.wirth@mb.tu-chemnitz.de

Translator: Michael Lorenz, Magdeburg
Translation: TECH GmbH, Magdeburg, www.t-ech.de

ISBN 978-3-642-03634-7 e-ISBN 978-3-642-03635-4
DOI 10.1007/978-3-642-03635-4
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2009939127

Cover design: WMXDesign GmbH, Heidelberg

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

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.

Special thanks go to Dr. Elke Glistau (Otto von Guericke University, Magdeburg), Gert Kobylka Dipl. Ing. and Kerstin Rockstroh (Chemnitz University of Technology) for their consistently professional assistance.

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

Contents

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 (**G**esetz zur Regelung des Rechts der **A**llgemeinen **G**eschäfts**b**edingungen)
AMM	Auxiliary manufacturing material
APS	Advanced Planning System
AR	Augmented Reality
ArbStättV	German regulations governing the workplace (**Arb**eits**stätt**en**v**erordnung or Workplace Ordinance)
ASR	German workplace guidelines (**A**rbeits**s**tätten**r**ichtlinien)
AWSA	Assembly workstation area
BAT	Biological Tolerance values (**B**iologischer **A**rbeitsstoff-**T**oleranz-Wert)
BGB	German Civil Code (**B**ürgerliches **G**esetz**b**uch)
BMV	German Federal Ministry of Transport (**B**undes**m**inisterium für **V**erkehr)
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

CONWIP	Constant Work in Process
CS	Components and parts suppliers
DBS	Database System
DC	Direct current
DIN	German Institute for Standardization (**D**eutsches **I**nstitut für **N**ormung)
DNC	Distributed (or Direct) Numerical Control
EKA	Exposure Equivalent for Carcinogenic Substances (**E**xpositionsäquivalent für **k**rebserzeugende **A**rbeitsstoffe)
ERP	Enterprise Resource Planning system
FAQ	Frequently asked questions
FEM	European Federation of Materials Handling (Federation Européenne de la Manutention)
FMC	Flexible manufacturing cell
FTT	(Jigs &) Fixtures, tools and testing equipment
GeWo	German Trade Commerce and Industry Regulation Act (**Gew**erbe**o**rdnung)
GI	Goods inwards
GO	Goods outwards
HGB	German Commercial Code (**H**andels**g**esetz**b**uch)
ICP	In-cyclical parallelism
ISO	International Organization for Standardization
JIS	Just in sequence
JIT	Just in time
LAN	Local Area Network
LTUs	Conveyor
MAP	Manufacturing Automation Protocol
MDA	Machine data acquisition
MEK	Maximum Emissions Concentration (**M**aximale **E**missions-**K**onzentration)
MES	Manufacturing Execution Systems
MIK	Maximum Immissions Concentration (**M**aximale **I**mmissions-**K**onzentration)
MMO	Multiple machine operation
MSS	Management Support System
NC	Numerical control
NS	Number of shifts
OEM	Original Equipment Manufacturer
OP	Operation
OPC	OLE (object linking and embedding) for Process Control
OSACA	Open system architecture for controls within automation systems
OSI	Open System Interconnection

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 (**T**echnische **G**üte- und **L**ieferbedingungen)
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 (**T**echnische **R**icht**k**onzentration)
TÜV	German Technical Inspection Association (**T**echnischer **Ü**berwachungs**v**erein)
UDM	Universal lathe
UVV	German accident prevention regulations (**U**nfall**v**erhütungs**v**orschriften)
VBG	German employers' liability insurance association (**V**erwaltungs-**B**erufs**g**enossenschaft)
VDI	Association of German Engineers (**V**erein **D**eutscher **I**ngenieure)
VDE	German Association for Electrical, Electronic & Information Technologies (**V**erband **d**er **E**lektrotechnik Elektronik Informationstechnik)

VR	Virtual Reality
WHG	German Federal Water Act (**W**asser**h**aushalts**g**esetz)
WLAN	Wireless Local Area Network
WMS	Workflow management system
WP	Wearing parts
WTR	Working time requirement

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.

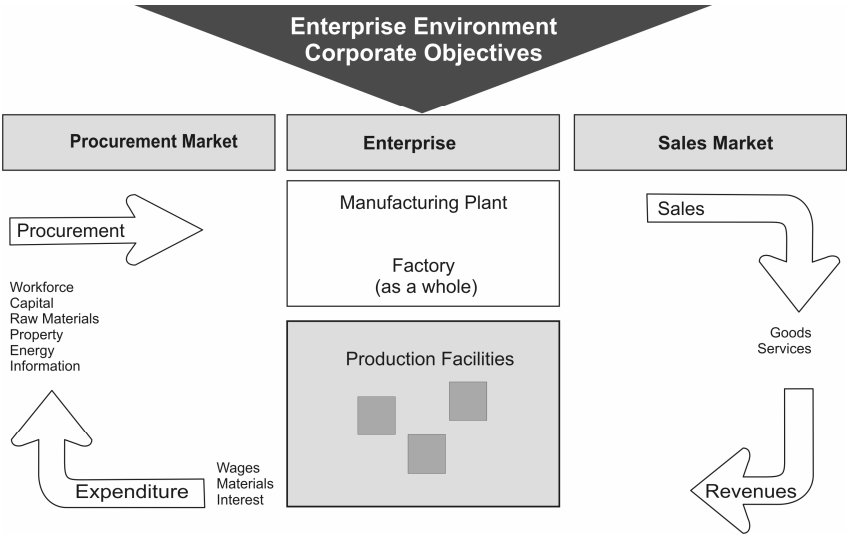

Fig. 1.1 Production facilities as part of an enterprise (Schmigalla 1995)

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.

M. Schenk et al., *Factory Planning Manual*, DOI 10.1007/978-3-642-03635-4_1,

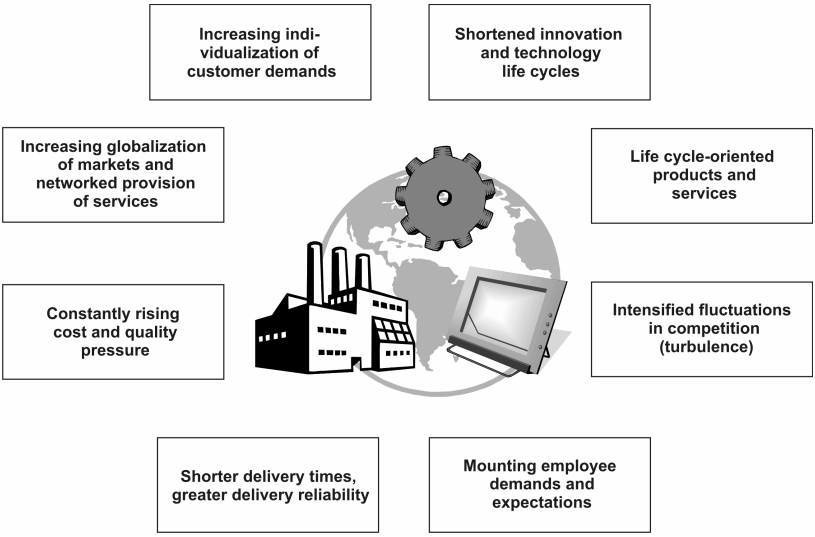

Fig. 1.2 Significant changes for manufacturing enterprises

Maximization of profitability and, in addition, flexibility, adaptability and attractiveness will continue to be corporate objectives in the future (fig. 1.3).

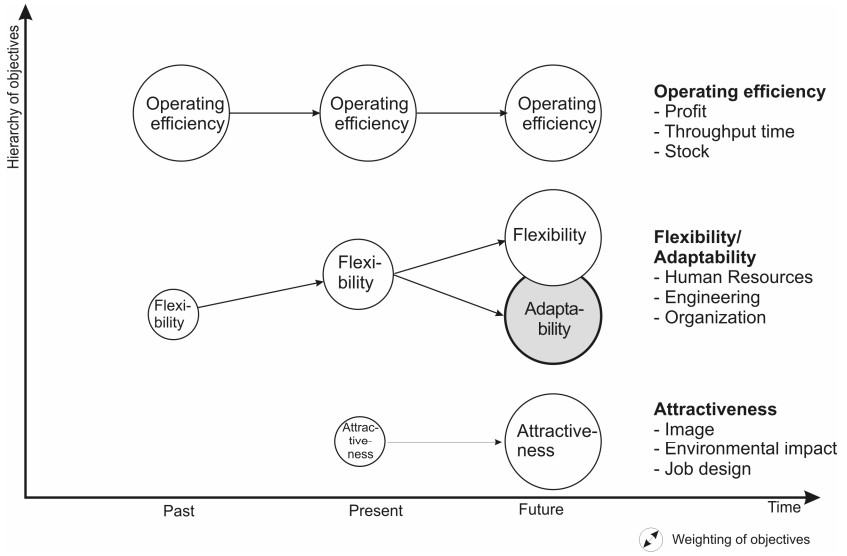

Fig. 1.3 Future objectives (Günther 2006)

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).

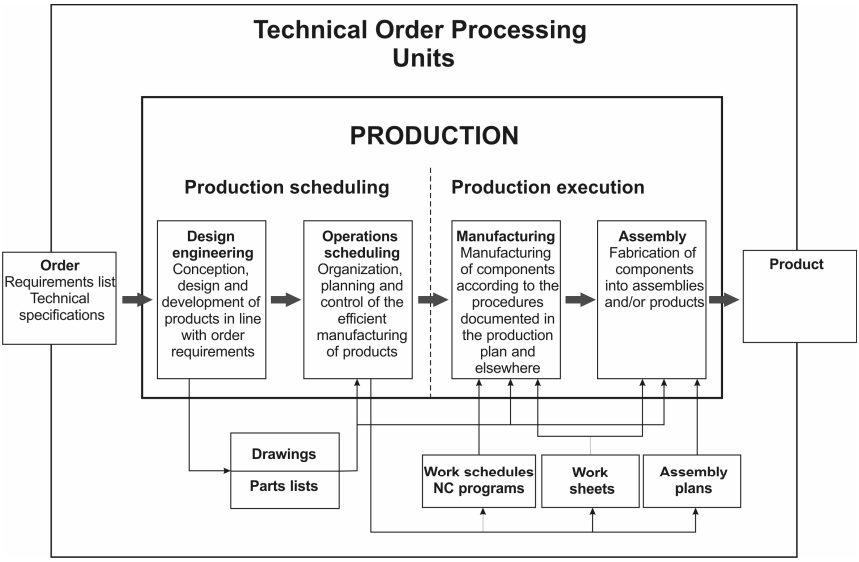

Fig. 1.4 Technical order process

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.

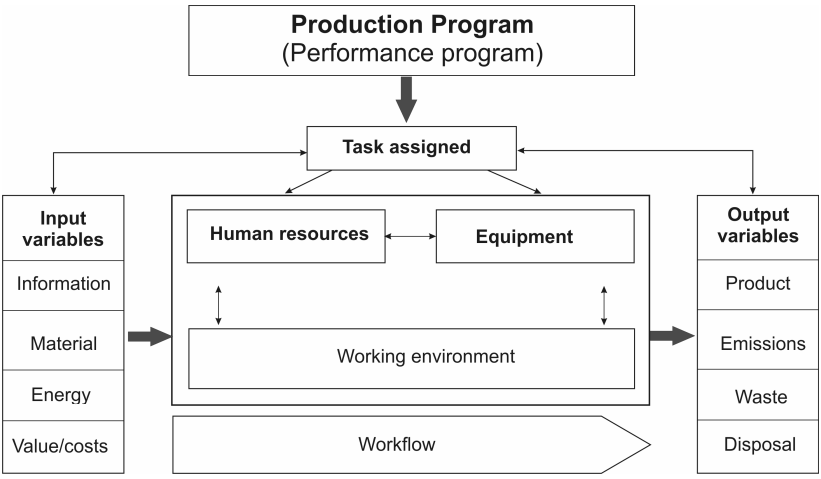

Fig. 1.5 The basic workshop model (Warnecke 1992)

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).

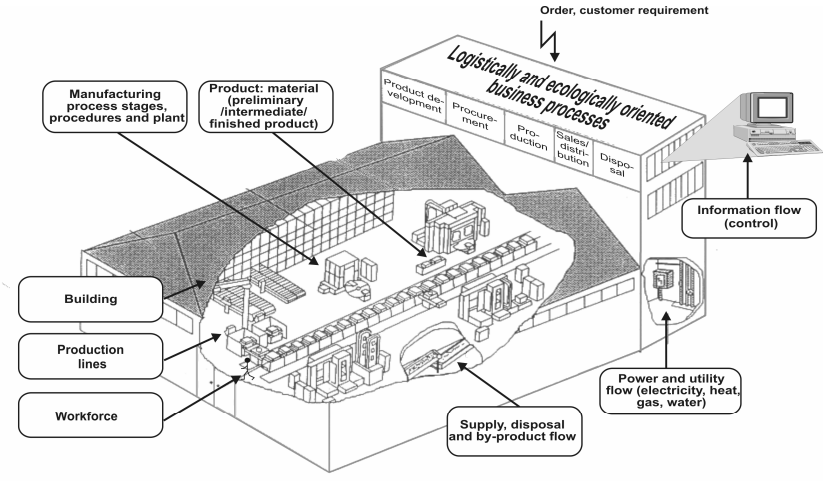

Fig. 1.6 The organizational areas and facilities of a manufacturing site

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.

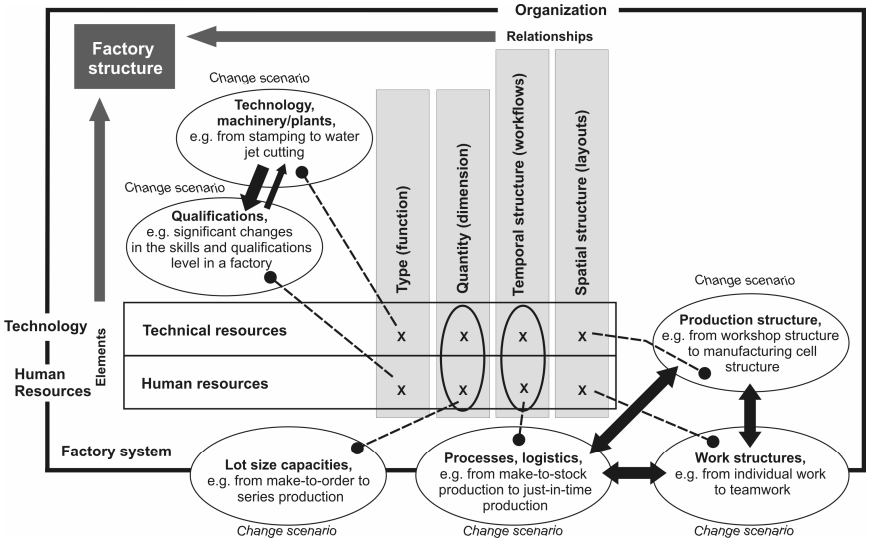

Fig. 1.7 Selected change scenarios (Hildebrand 2005, p. 19)

Characteristic	Attributes			
Enterprise size	Small enterprise	Small and medium-sized enterprise	Large enterprise	
Product size	Micro	Small	Medium	Large
Production process	Continuous	Batch	Combined	
Investment period	Short-term	Medium-term	Long-term	
Location strategy	Local	Regional	National	Global
Location changes	Mobile	Permanent	Combined	
Factory orientation	Process	Product	Workforce	Buildings
Type of production	Make-to-order production	Small batch	Medium batch	Mass
Value-added stages	Marketing	Research/ development	Procurement	Production	Sales & Marketing	Service
Operator models	Buy	Rent	Lease	
Production stages	Single part	Structural elements, components	Assembly, system assembly	Units (vehicles)	Plant systems
Networking	Autonomous factory	Networked factory	Competence networks	Virtual factory
Use	Reuse	Further use	Recycling	Disposal

Example: standardized factory

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).

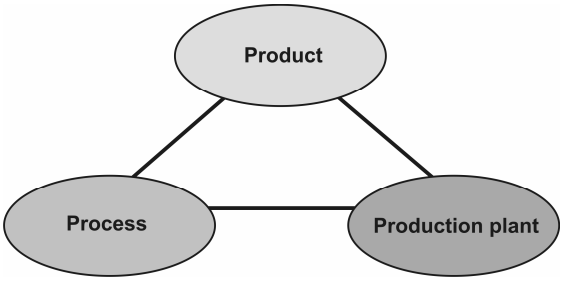

Fig. 1.9 Relationship structure between product, production process and plant

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.

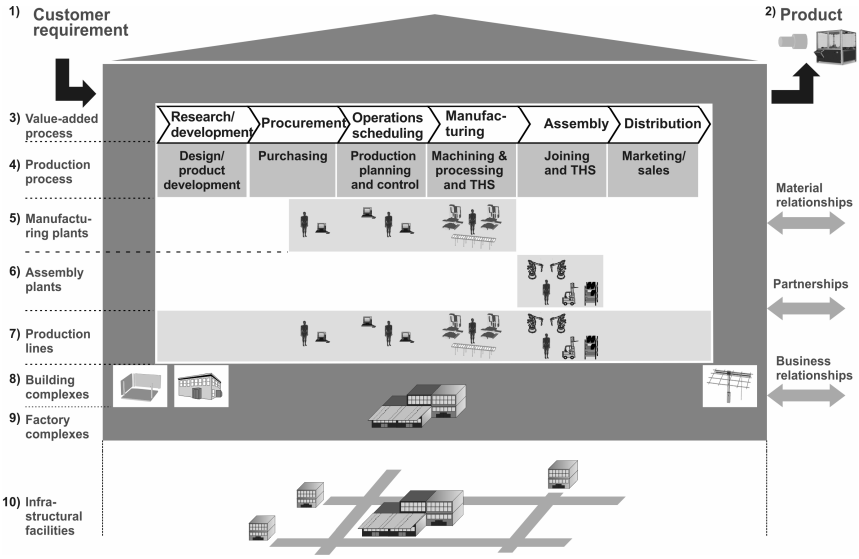

Fig. 1.10 A factory/production facility's product, processes and plants (Schenk, Wirth 2004, p. 18)

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.

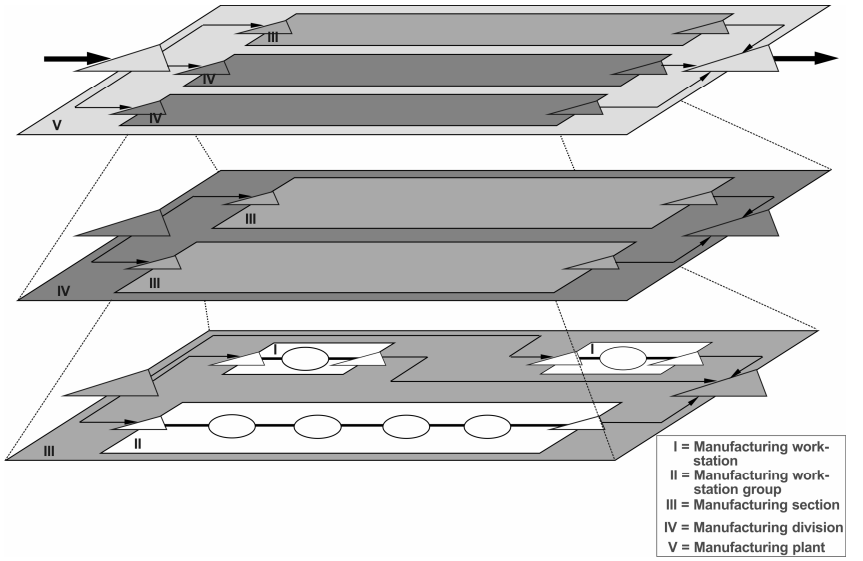

Fig. 1.11 Hierarchical organization of a production facility

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.

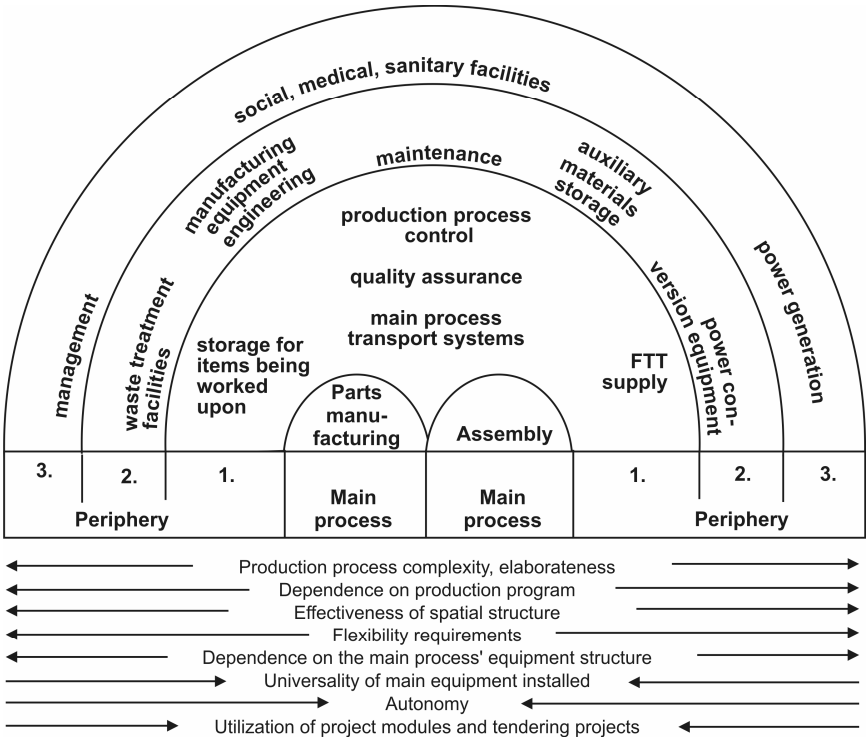

Fig. 1.12 Peripheral areas of the main production processes

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	Energy flow systems	Information flow systems
Product/material flow systems - Parts (unfinished/finished parts) - Units (assemblies) Finished products - Purchase parts and standard parts - THS equipment		**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
FTT flow systems - Jigs & fixtures - Tools - Testing equipment		
Supply and disposal/building flow systems		**Production execution information flow systems**
- Auxiliary manufacturing materials - Waste (turnings & chips, parts scrap) - Air (fresh air/exhaust air) - Water (drinking and fresh water/ wastewater)	- Electrical energy (power units, heating, IT) - Compressed air / hydraulic system - Technical gases - Indoor air (air conditioning) - Steam, hot water (heating)	- 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.

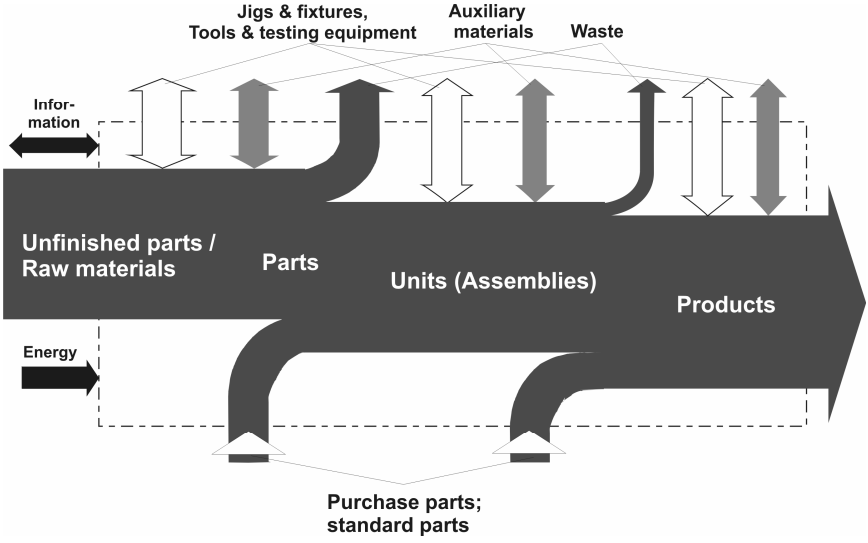

Fig. 1.14 Product flow on a machinery production line (Sankey diagram)

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

Product and production process-related requirements	Human resource-related requirements
Product technology	Social and sanitary protection
Production technology	Occupational safety, workspace climate
Security of supply	Air conditioning
Security of disposal	Occupational ergonomics/usability
Climate	Color scheme
Flow reliability	Minimal noise, immission control
Connections/interfaces	Illumination/daylight/lighting
Flexibility/adaptability	Collision protection, protection from harmful interference
	Level of protection, protection against fire
	Controllability and manageability
Plant-related requirements	**Management-related requirements**
Accessibility and freedom of movement	Administrative tasks and equipment
Access, openings	Functionality of management
Universal use	Communication, IT equipment (EDP)
Upgradability	Office space
Configurability, modularity	
Utilization of space and spatial geometry	

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

Planning				**Commissioning**	
Analyses and Studies		**Planning tasks**		**Contracts (no services)**	
Raw materials inspections	x	Factory planning		Sale of products	x
Technical testing, analysis	x	Project management (schedule and cost control)	x	Renting	
Troubleshooting/needs assessment	x	Procurement	x	Sale of use/lease contract	x
Site inspections	x	Documentation	x	Sale of service / operator model	x
Market research / market studies		Network management	x	Replacement parts contracts (defined lead times)	x
Value analyses		Solving of interface problems	x	Maintenance contracts	x
Profitability analyses / return on capital studies	x	Organizational development		Service contracts	x

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

				timization	
Recruiting services		**Customer communication**		Remote optimization of plant and processes	
Data management		Complaint management	x	Retrofitting and upgrading	x
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	x
ODA: Order (operating) data acquisition, storage, processing and evaluation (production statistician)	x	Provision of product documentation (manuals)	x	Machine relocation	x
Maintenance		Recording of complaints customer suggestions/problems	x	**Reuse**	
Cleaning of machinery	x	Reference customer visit	x	Development of de-integration plans	
Preventative maintenance	x	User groups (customer exchange of experience)	x	Acceptance of returned machinery, equipment, used parts	x
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	x	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	x
Manufacturer-independent repair of competitor's products				Large-scale inspection and plant refurbishment	
				Revamping	x
				Conversion / refitting	x
				Overhauling, retrofitting	
				see also system development.	
				Disposal	
				Withdrawal from service	
				Organization of decommissioning process	
				Scrapping of old equipment	
				Recycling of materials	
x = preferred engineering services				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.

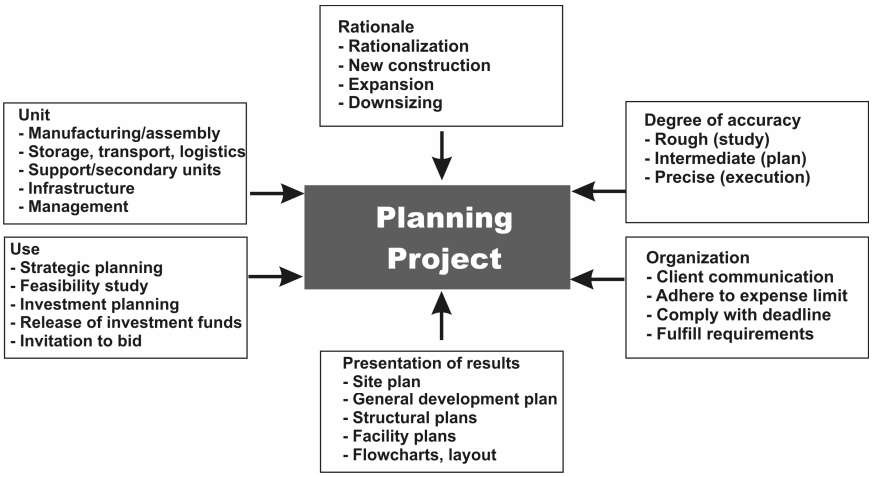

Fig. 2.1 Features of a planning project

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:

M. Schenk et al., *Factory Planning Manual*, DOI 10.1007/978-3-642-03635-4_2,

Table 2.1 Production-related technical disciplines

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

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).

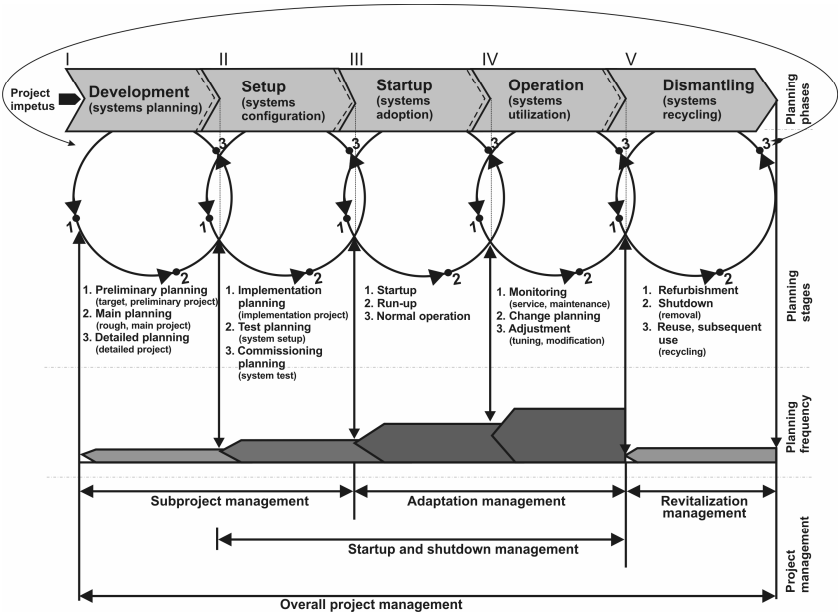

Fig. 2.2 Production facility and factory life cycle design planning phases and stages (Schenk, Wirth 2004)

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

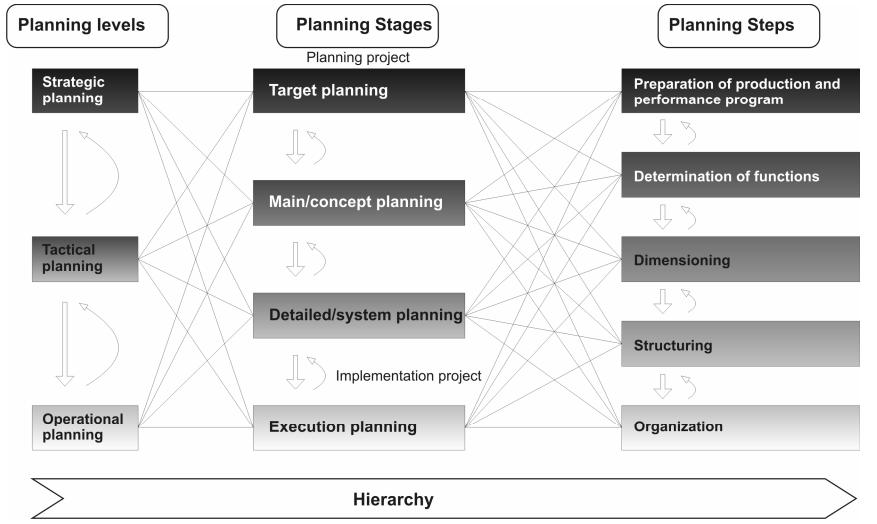

Fig. 2.3 Views of the planning processes