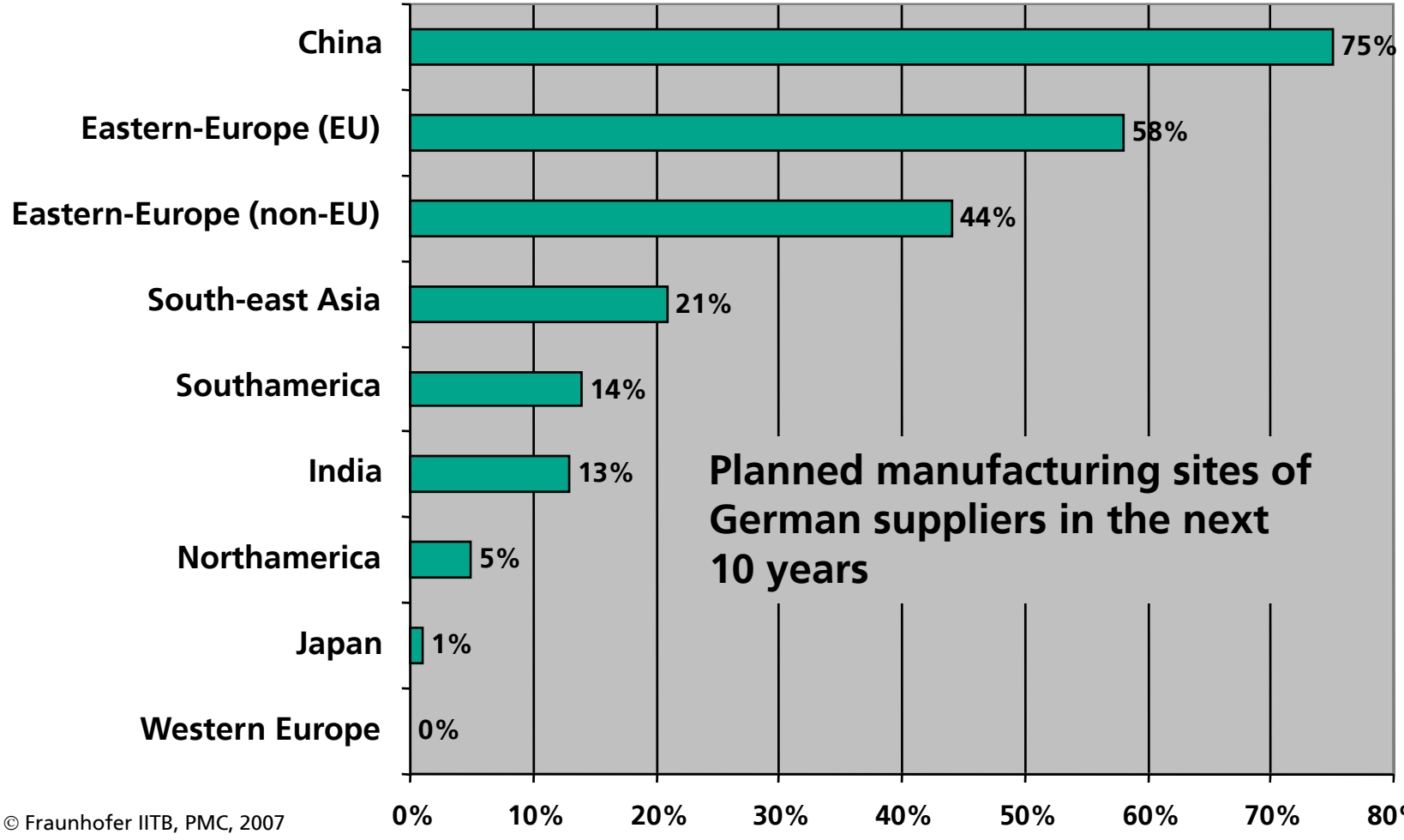
Systems for Production Control and Production Planning

- Lecture on manufacturing and its IT-systems -

Fraunhofer Institut Informations- und Datenverarbeitung

Shenyang, November 22, 2007

„Chart of the week“ (source: Automobilwoche 2006)



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   Fraunhofer IITB and its business unit production monitoring & control

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4. **Trends in manufacturing;**
   current developments in manufacturing companies

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   Manufacturing execution systems (MES)

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1. Short introduction to the lecturer's organization:

Fraunhofer IITB and its business unit production monitoring & control

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1. Short introduction to Fraunhofer IITB

- **Applied research**
- **56 institutes**
- **40 locations in Germany**
- **12 800 employees**
- **1 Billion € budget**

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1. Short introduction to Fraunhofer IITB (2)

1787 –1826
Josef von Fraunhofer

- **Fraunhofer society:**
  - 12.700 'applied scientists' focused on R&D-services
  - 1 bio € revenue
  - 58 institutes including overseas offices

- **Core competencies of IITB business unit:**
  - Real time applications for production monitoring, control and maintenance support
  - Consulting for Manufacturing Execution Systems
  - Optimization algorithms for manufacturing scheduling and sequencing
  - Detailed know-how of manufacturing and assembly processes in discrete manufacturing

- **Customers:**
  - DaimlerChrysler, plants Bremen, Wörth, Sindelfingen
  - Siemens A&D ("PCS7 Batch")
  - ThyssenKrupp Steel
  - 'MES-software' suppliers (Manuf. Execution Systems)

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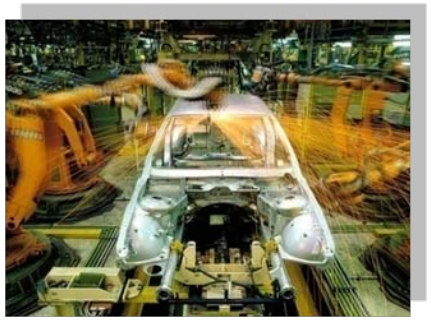
1. Services and products of IITB's business unit PMC

ProVis.Agent®



Production monitoring

- Shared realtime applications for facility monitoring
- Business intelligence tools for KPI calculation
- Assisting functions for control rooms
- Visualization and SCADA-functions
- Software agents in realtime systems

FLS-NEXT
THE NEXT GENERATION

INNOVATIONSPREIS 2007
initiative mittelstand
AUSZEICHNUNG WEB 2.0

Innovative MES-components

- Optimization algorithms for manufacturing
- Concepts for lean manufacturing control
- Planning and scheduling
- Ambient Intelligence in manufacturing
- Applications for digital production

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1. Examples for current projects

Annealed (1.250°C) steel slab, app. 150 t, process control and monitoring system made by FhG-IITB

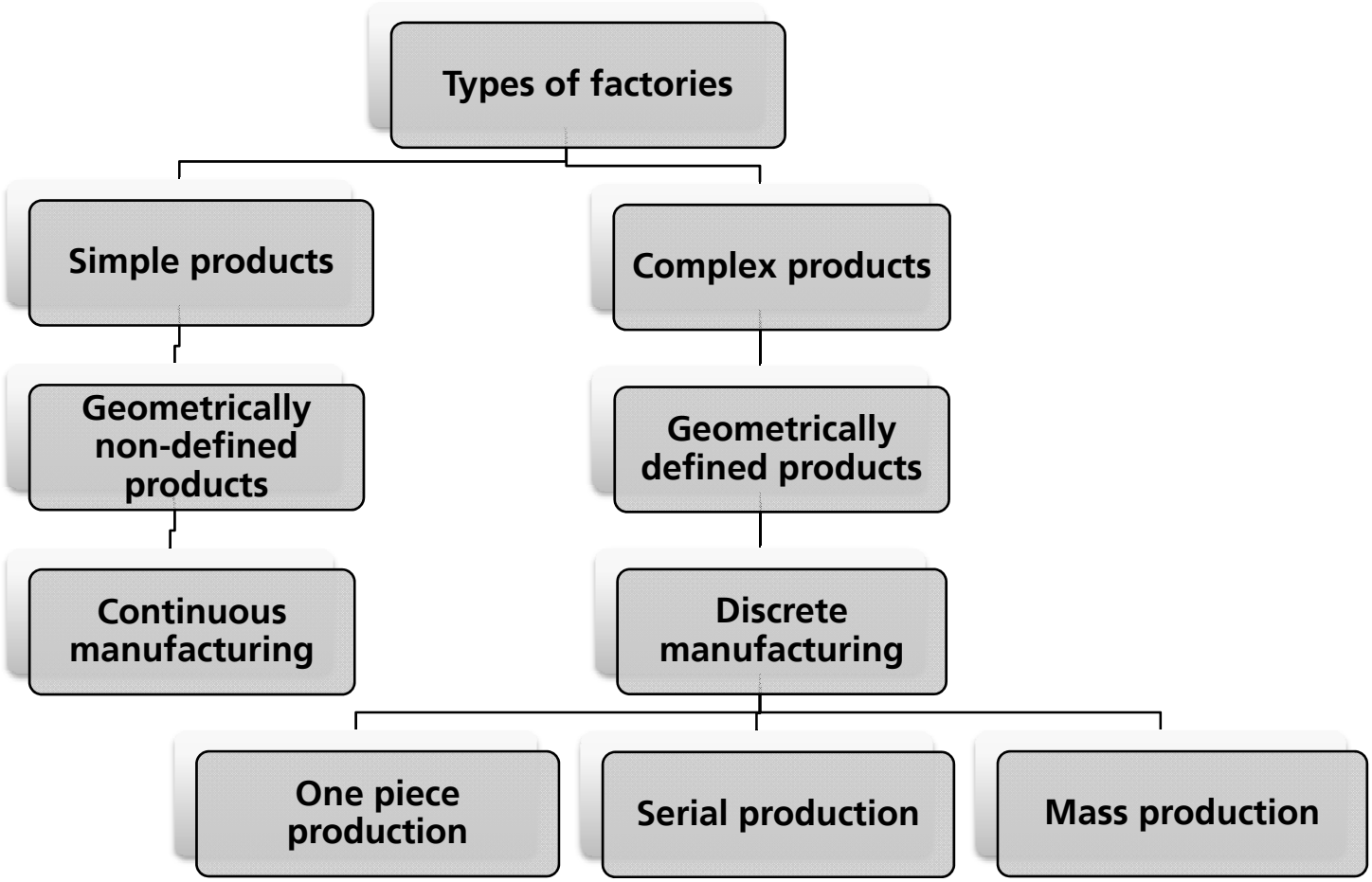
- **Production monitoring system ProVis.Agent, DaimlerChrysler AG, plants Bremen und Woerth, in body, paint, assembly incl. hotline and service**
- **Development of IO-Module (‚Primary Data Manager - PDM') incl. PLC-connection via 'Integra-channel' for Siemens, business unit A&D**
- **Production monitoring & control system for 20 annealing furnaces, ThyssenKrupp Stahl AG, Duisburg plant incl. hotline and service**
- **Cooperation with Siemens A&D for production monitoring systems (PCS7) and OPC-tools applied to process industries (food, beverage, etc.)**
- **Concept for plug-and-work engineering, PLC-programming and process pictures for Hottinger Maschinenbau GmbH, Mannheim (Germany)**
- **Evaluation of strategies for manufacturing control and their impacts on manufacturing execution functionalities, MPDV GmbH, Mosbach (Germany)**

Source: DaimlerChrysler

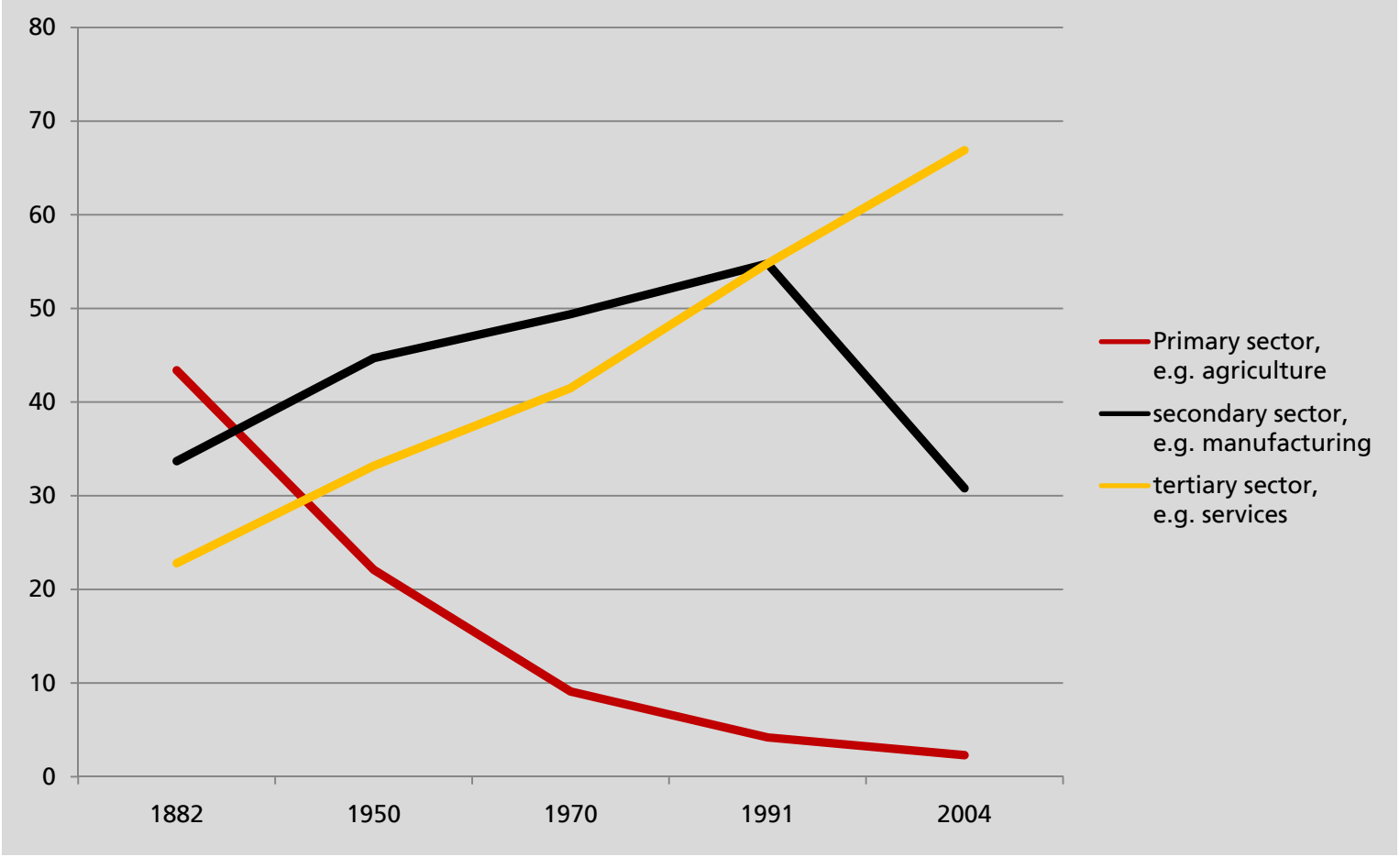
2. Production: what is it all about?

A framework for factory planning and operations

2. Factory types for production of goods (source: Spur, G.: Fabrikbetrieb)



2. How the sectors of the German economy develop



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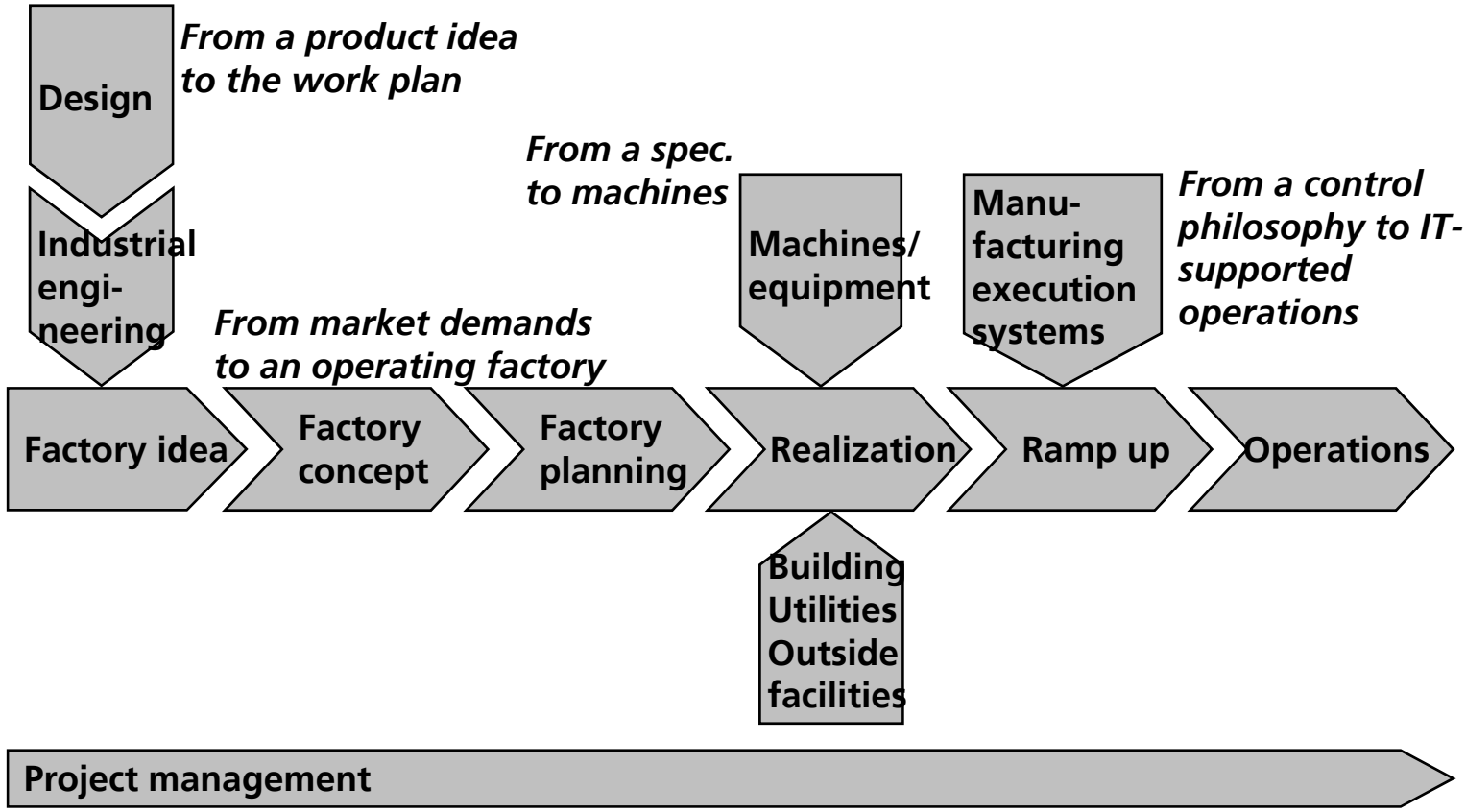
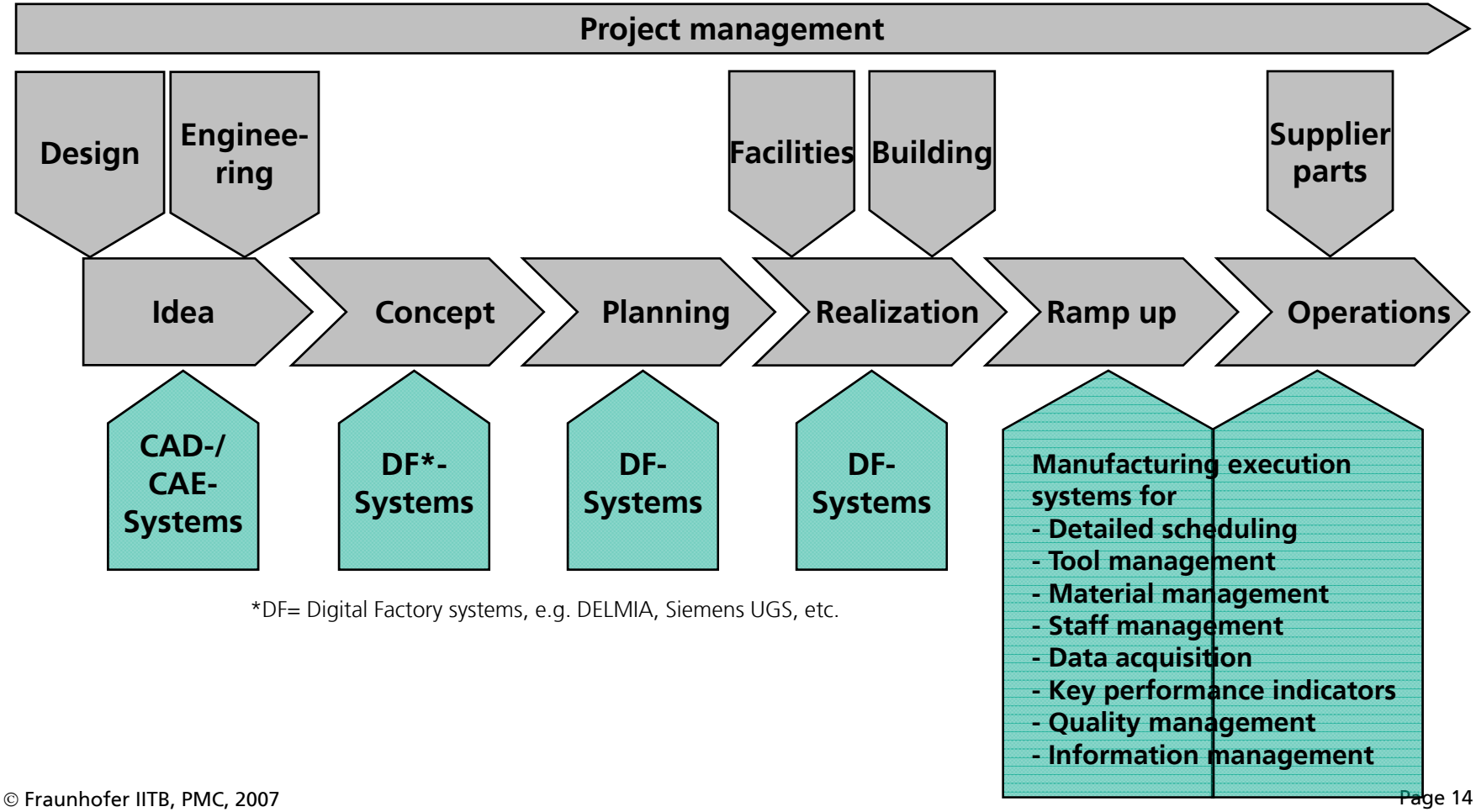
2. Reference model for factory planning



2. Reference model for factory planning: connection of planning and operations



*DF= Digital Factory systems, e.g. DELMIA, Siemens UGS, etc.

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3. Strategies for modern production:

control and logistic approaches

3. Current situation of manufacturing companies (1)

Flexibility

- **Traditional markets, e.g. machines, automotive, ship-building, etc., are saturated**
  ➔ over capacities, buyer-markets, flexibly acting markets, high requirements concerning flexibility

Variants

- **Markets are increasingly segmented, products are to a maximum degree customized**
  ➔ High degree of variants and therefore complexity in production and assembly, lot size 1 also in serial production

Supply Chain

- **Global competition and international work share also in small and medium sized companies**
  ➔ Product quality and know-how about processes are common xxx, international supply networks, high competitive pressure

3. Current situation of manufacturing companies (2)

Time

- **Short life cycles, caused e.g. by permanent innovation in microelectronics**
  ➔ Lead time and delivery times become strategic performance indicators

Organization

- **Qualified staff is entitled to self-determination, entrepreneurial spirit conerning their work**
  ➔ small, self-organizing units in manufacturing, no hierarchies, KAIZEN (continuous improvement)

Information techn.

- **Realtime-IT in manufacturing from machine controllers up to the ERP-system, new software technologies**
  ➔ Approaches of shared, decentralized intelligence will become accepted

3. Manufacturing and control strategies (1)

Job shop manufacturing
(turning shop, milling shop, grinding shop, paint shop...)

Characteristics:

- **Equivalent equipment is concentrated in manufacturing shops, e.g. all turning machines in the turning shop. With multi-level products the material flow gets very complex (spaghetti!)**

- **Work flow is bound to manufacturing of lots; when the last part of a lot is finished the entire lot is transported to the next production step.**

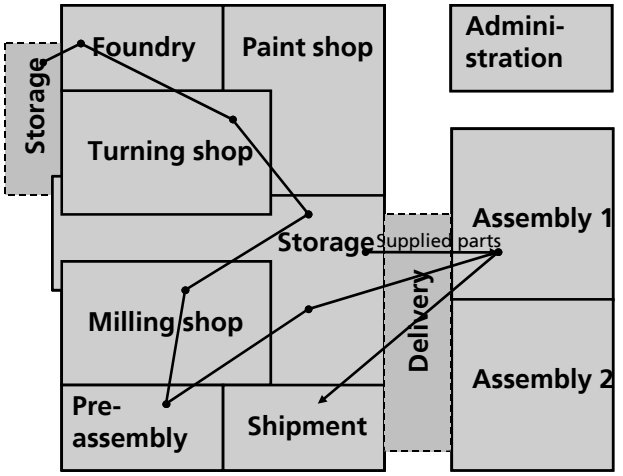
IITB traffic light	
Flexibility	
Variants	
Supply Chain	
Time	
Organization	
Information techn.	

not applicable

neutral

applicable

Example: factory layout of a job shop manufacuring (source: Röhrig, M.)



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3. Manufacturing and control strategies (2)

Cell manufacturing – decentralized units in production

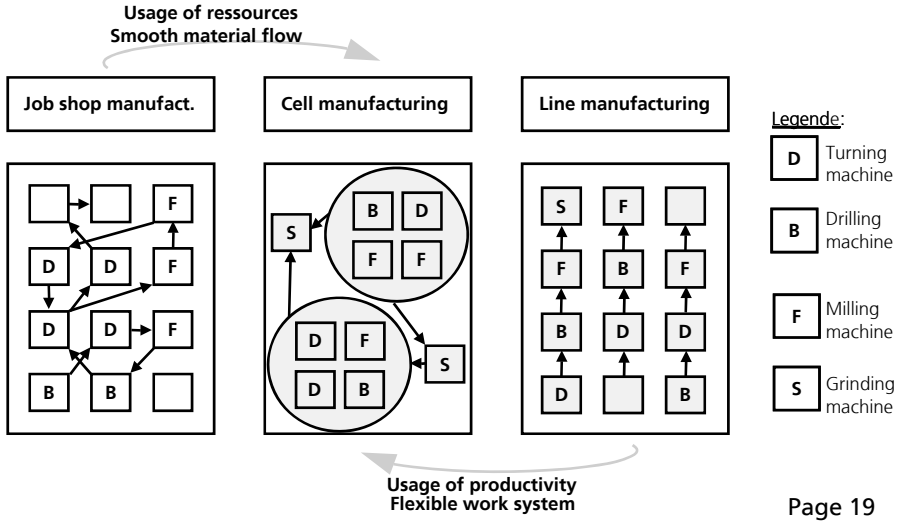
Characteristics:

- **Workers produce parts, sub-assemblies or finished goods completely, if possible in group technology. Workers are in charge of control and quality management.**

- **Applying cells means manufacturing part families, that means parts that are similar to each other.**

IITB traffic light	
Flexibility	
Variants	
Supply Chain	
Time	
Organization	
Information techn.	

Benfits from a combination of job shop and cell manufacturing (source: Hauertmann, W., et.al.)



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3. Manufacturing and control strategies (3)

Line manufacturing (automated / manual)

Characteristics:

- **Machines and production steps are arranged according to the production flow**
- **Used for large order numbers, specialized equipment, mostly machines with fixed cycle times**

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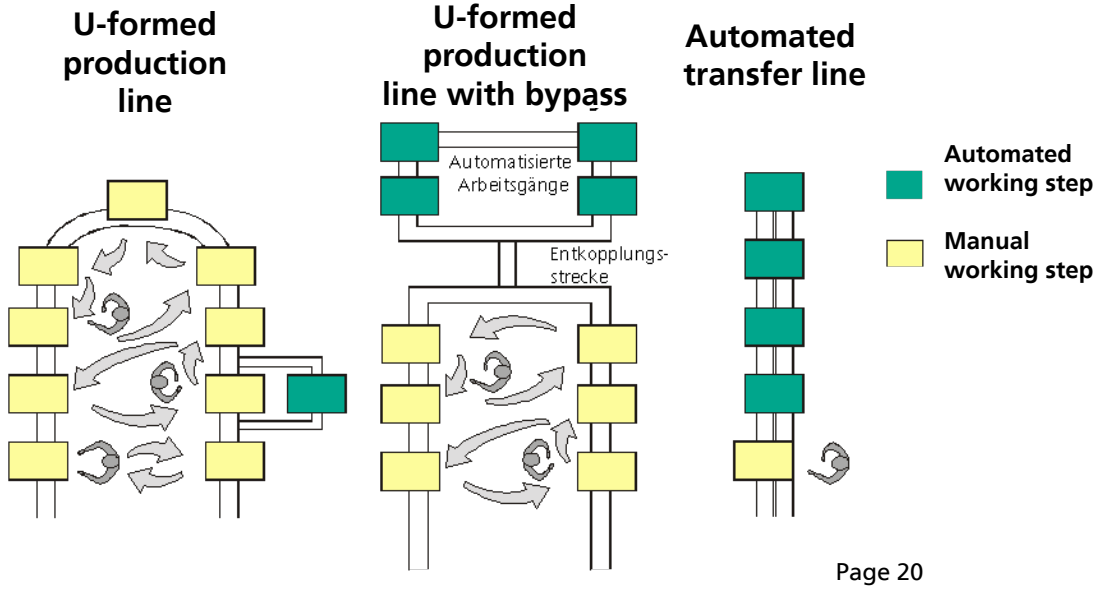
Flexibility	
Variants	
Supply Chain	
Time	
Organization	
Information techn.	

Examples for line manufacturing (source: IFA, Hanover)



3. Manufacturing and control strategies (4)

NEW: variant enabling manufacturing

Characteristics:

- **Manufacturing process is divided in variant neutral and variant building production steps.**
- **A special cell manufactures only parts without customer specific options; in the final cell customer specific options and variants are assembled including some machines, that produce customer specific options.**

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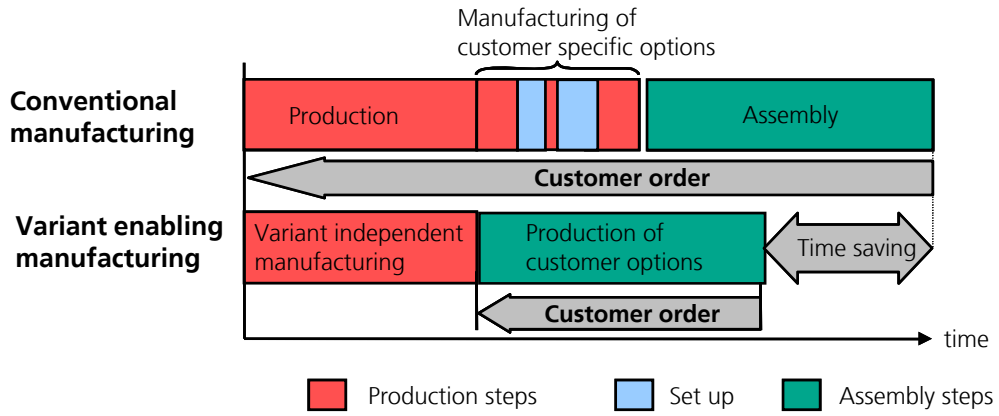
Flexibility	
Variants	
Supply Chain	
Time	
Organization	
Information techn.	

Model of a variant enabling factory (source: Röhrig, M.)



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3. Manufacturing and control strategies (5)

Push-control: MRP, MRP II, load dependant order control, cumulative quantity, etc.

Characteristics:

- **Central and batch oriented production planning and control; difficulties to short term reactions to unexpected changes on the shopfloor**
- **Central release of manufacturing orders according to methodology of termination**

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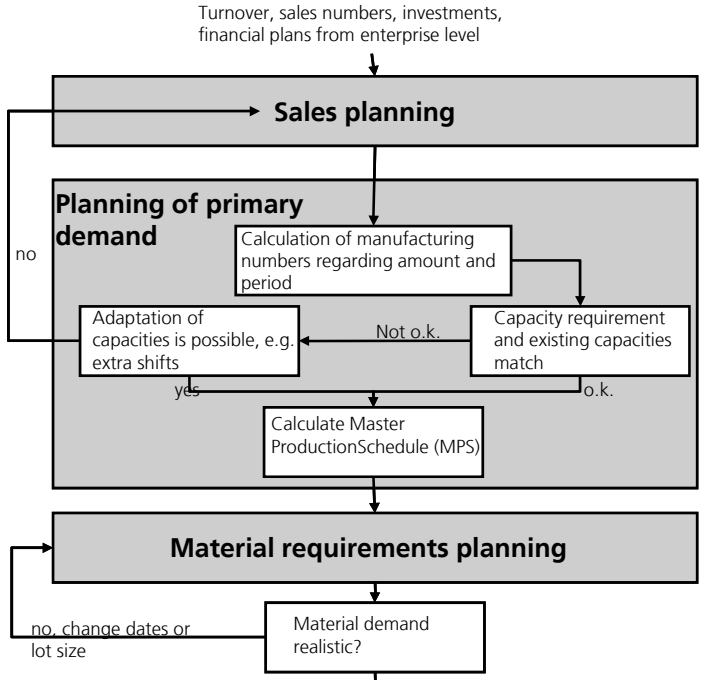
Flexibility	
Variants	
Supply Chain	
Time	
Organization	
Information techn.	

Draft MRP II process (source: Betriebshütte)



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3. Manufacturing and control strategies (6)

Pull control: KANBAN, CONWIP

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Flexibility	*
Variants	
Supply Chain	
Time	
Organization	
Information techn.	**

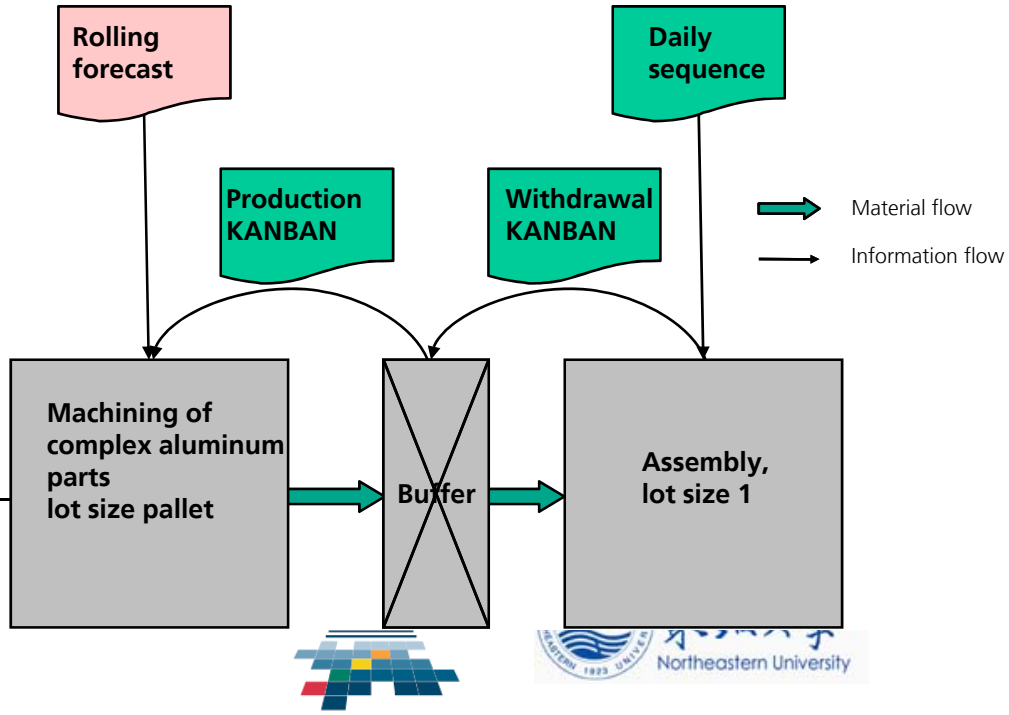
* Not applicable in case of unsteady part consumption

** Originally without use of IT-systems

Characteristics:

- **Only a real customer demand triggers manufacturing (like in the supermarket). Lot sizes are broken down to daily demands.**
- **The manufacturing process gets a signal, which parts are to be produced in a certain number at a certain point of time; the signal is triggered by a KANBAN.**

Material flow and information flow of a KANBAN controlled production (source: METROPLAN)



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3. Manufacturing and control strategies (7)

Pull control: ‚lean production‘

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Flexibility	
Variants	
Supply Chain	
Time	
Organization	
Information techn.	

Manufacturing strategy to eliminate waste; Characteristics:

- **Produce in the customer‘s cycle time: the ideal manufacturing line produces according to its customer‘s cycle or according to the customer‘s call-off**
- **One-piece flow: single process steps must be as close as possible in a process flow and should be synchronized**
- **PULL-system: if it‘s not possible to shape a continuous flow, the most efficient material flow is a PULL-System, connecting process steps throughout the value adding chain**
- **Control of only one process step: this pacemaker-process is directly ‘controlled’ by the customer demand**
- **Constant PULL of small units: use small load carriers instead of large wire metal boxes; reduce range of coverage and provide the line continuously by milk runs**

3. Practical use of strategies

Sophisticated terms made simple	Current use	Use in future
Job shop manufacturing	Traditional structures, „small and medium sized production“	Manufacturing and technology experts
Cell manufacturing	Part manufacturing, wide range of parts; physical	Part manufacturing and assembly, logical
Line manufacturing	Serial production; today use of automated equipment	Small range and serial production; automated and manual steps mixed
Variant enabling manufacturing	First applications in industry	Small range and serial production; driven by number of variants
Push control: MRP, MRP II, etc.	Traditional structures, often using SAP	Central control giving an objective for smaller units
PULL control: KANBAN, CONWIP	Assembly, provision of low value parts	Used between parts manuf. and assembly; also between companies
PULL control: lean production	Mostly serial production e.g. from automotive	Small range and serial production; commonly used
Local intelligence; agent control	First applications in industry	Shared production, PLC-/ CNC-controlled machines

3. Link between manufacturing and control strategies

Control strategies fitting manufacturing strategies; combinations found in practical use

	Push control: MRP, MRP II, etc.	PULL control: KANBAN, CONWIP	PULL control: lean manufacturing	Local intelligence; agent control
Job shop manufacturing	Well applicable	Well applicable	Partly applicable	Well applicable
Cell manufacturing	Not applicable	Well applicable	Well applicable	Well applicable
Line manufacturing	Partly applicable	Well applicable	Well applicable	Partly applicable
Variants enabling manufacturing	Not applicable	Well applicable	Well applicable	Well applicable

Not applicable
Partly applicable
Well applicable

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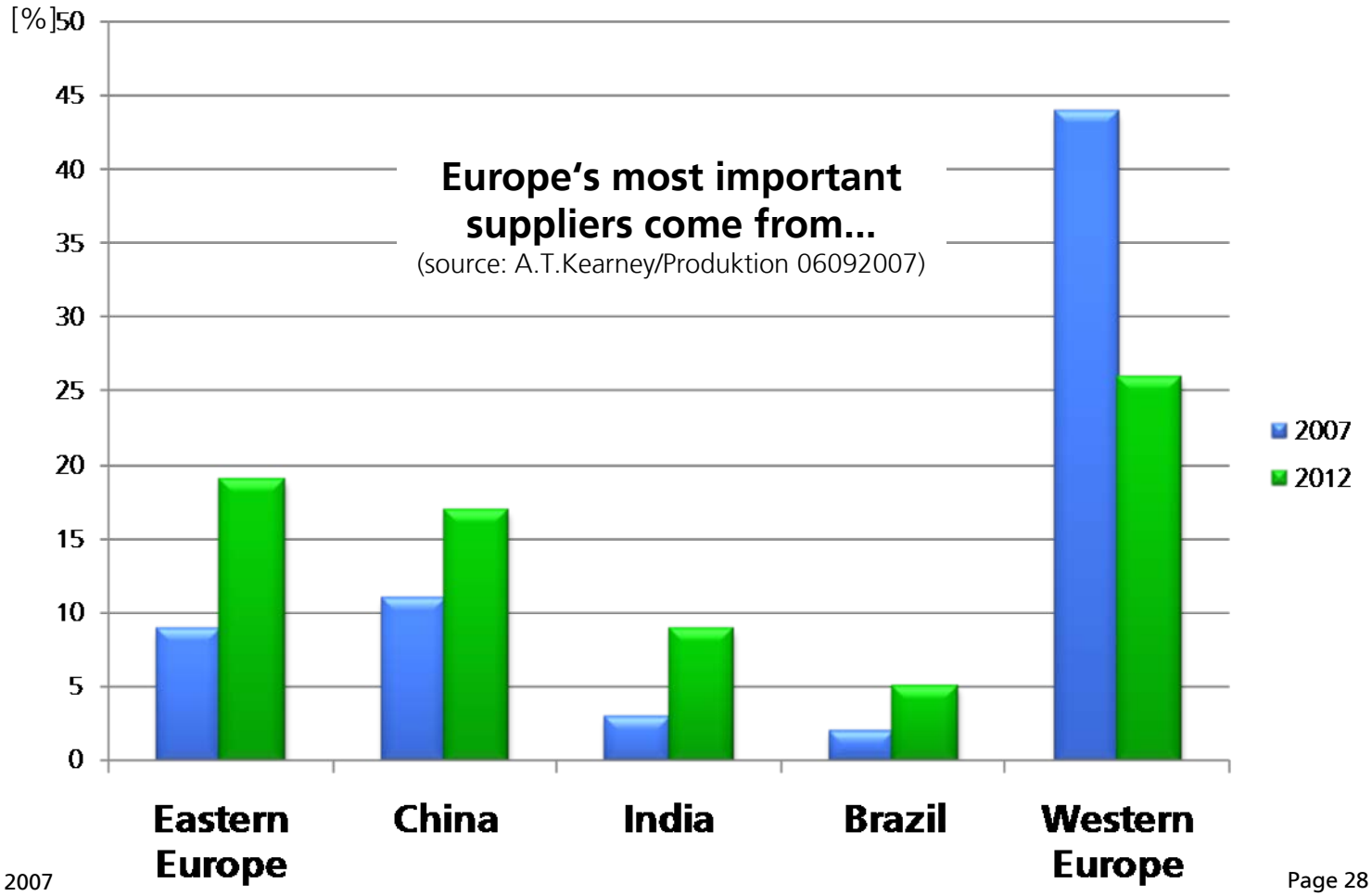
4. Trends in manufacturing;

current developments in manufacturing companies

4. Globalization



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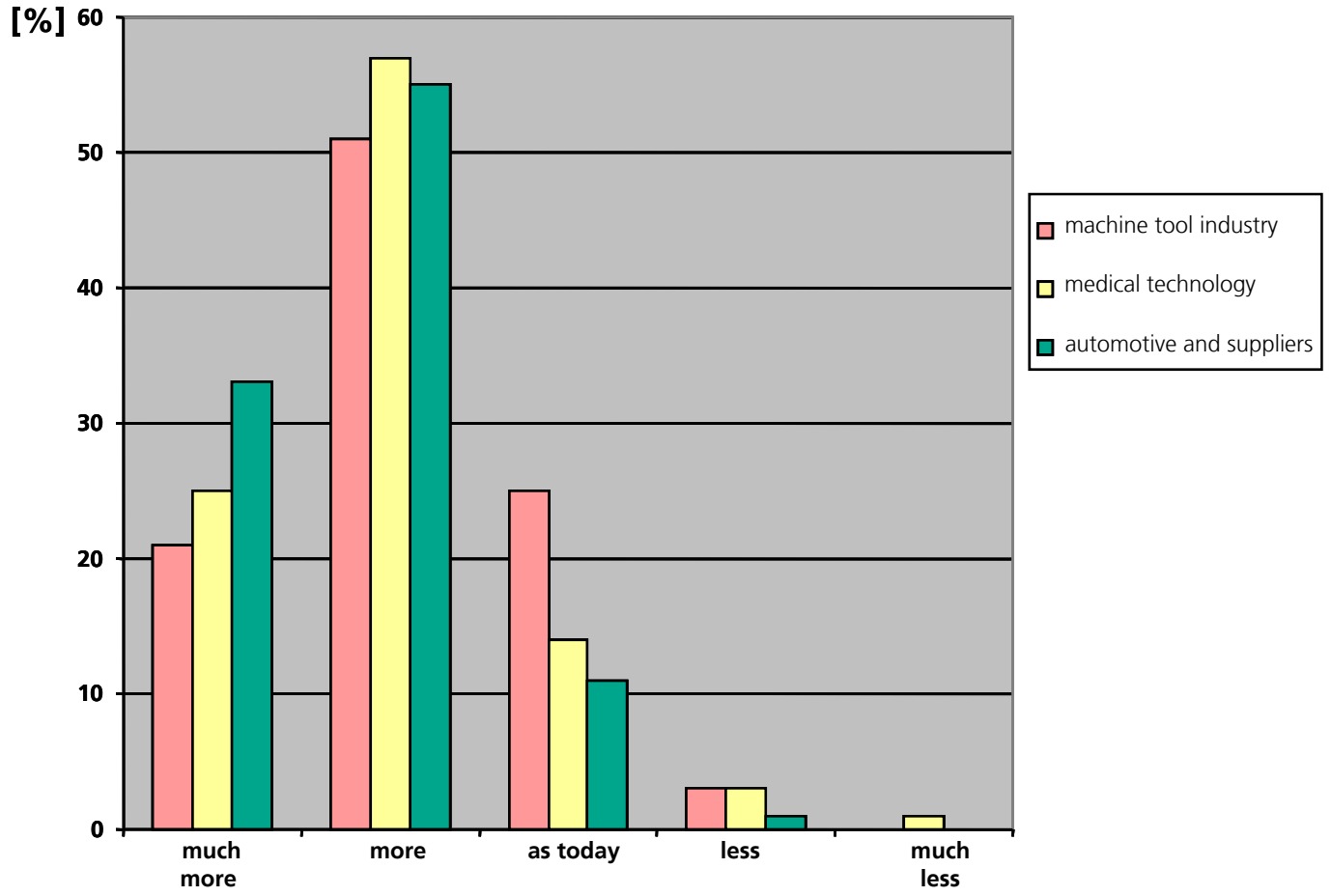
4. Increasing product variants

Development of product variants (source: requirements to tomorrows manufacturing technology, Fraunhofer ISI, September 2005;
n= 613



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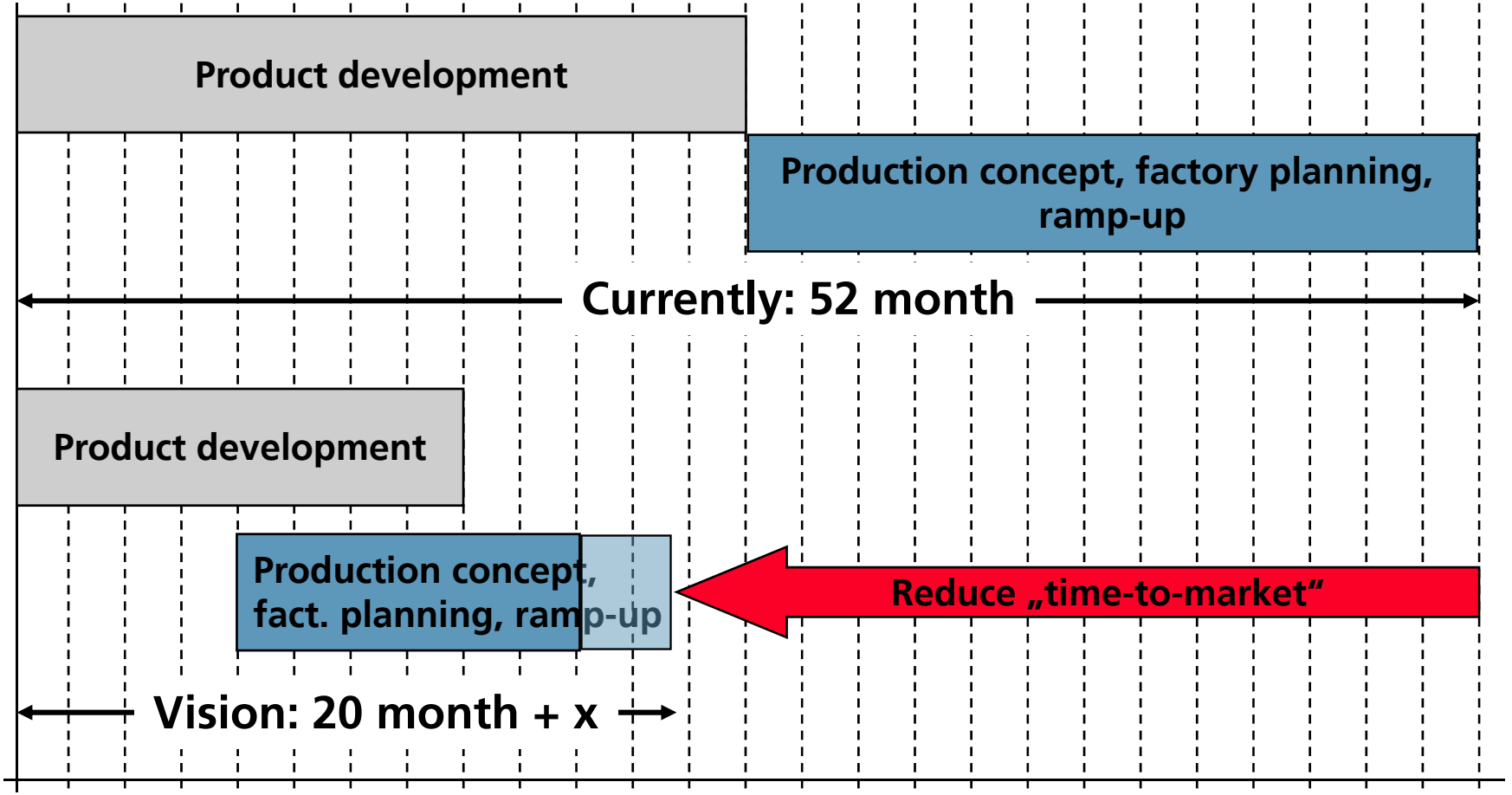
4. Short time to market



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Extension 1:

To cope with product variants

4.1 To cope with product variants (1)

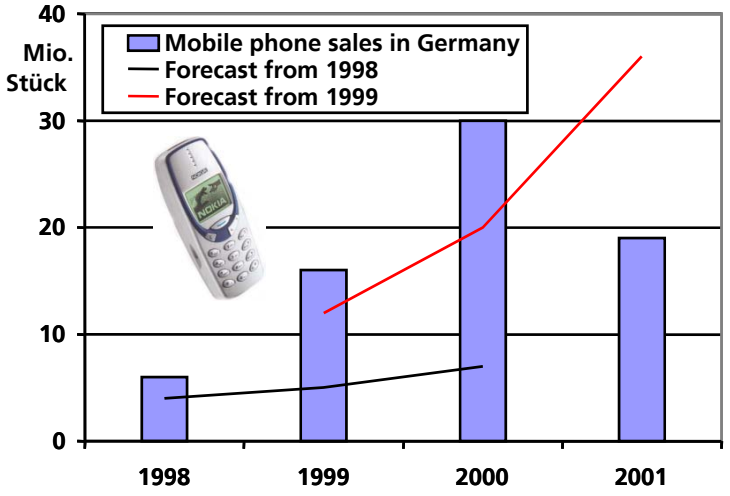
Dilemma of mass customization (source: Roehrig, M.)

Unsecure sales forecasts

Increasing variety

Reduced delivery times

Cost drivers



Increasing competition

Rationalization driver

Resulting requirements to manufacturing

High flexibility concerning volume

High variety

Short delivery times

Cost effectiveness

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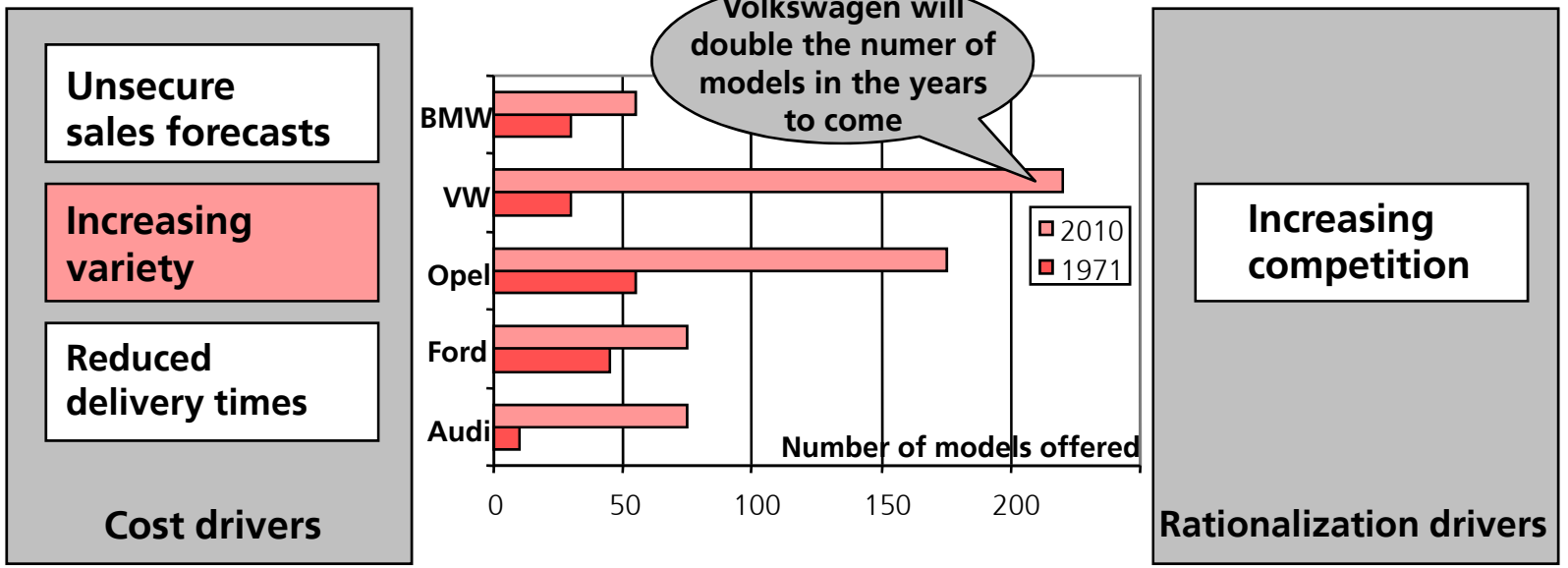
4.1 To cope with product variants (2)

Dilemma of mass customization (source: Roehrig, M.)

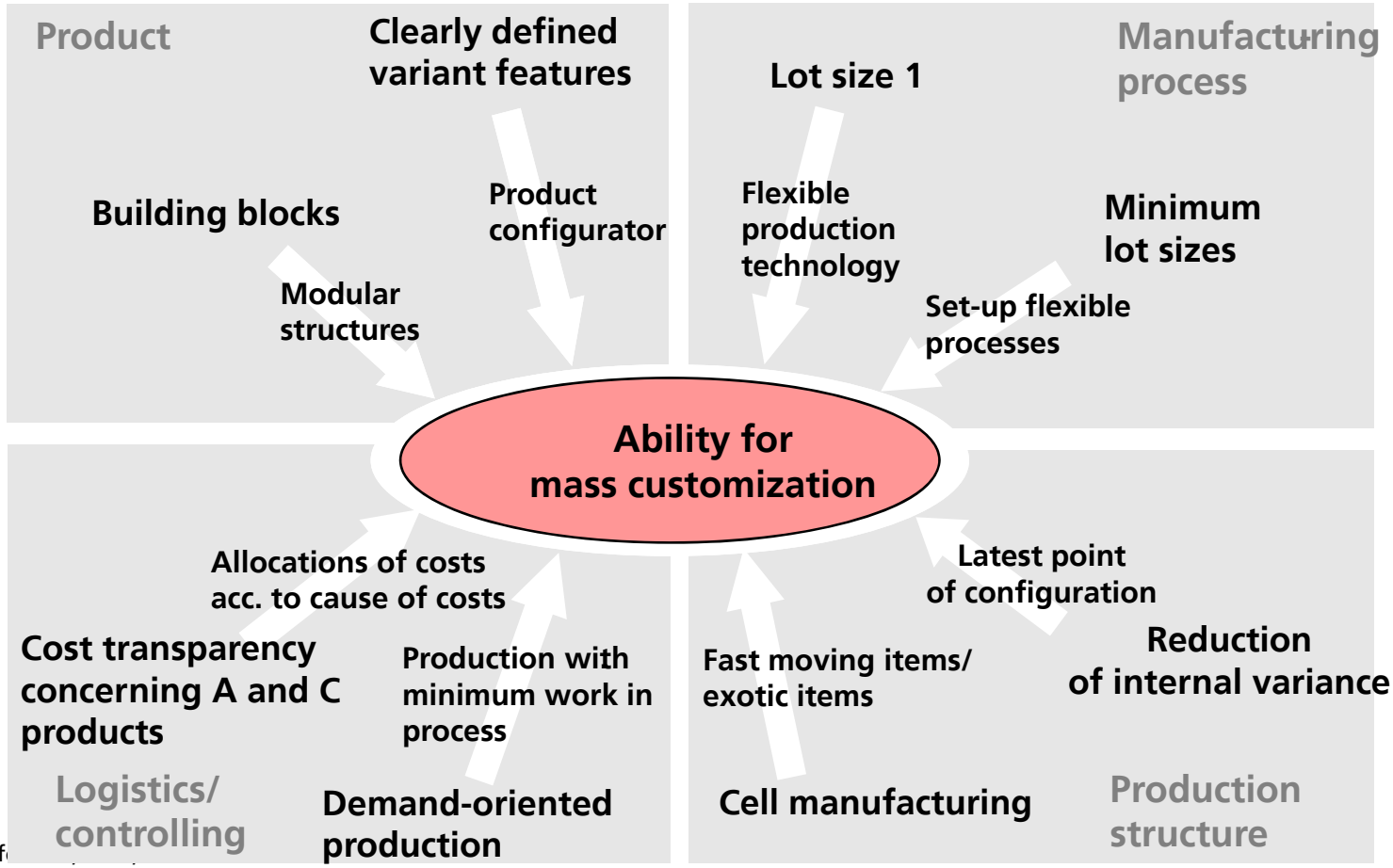


Resulting requirements to manufacturing

High flexibility concerning volume	High variety	Short delivery times	Cost effectiveness

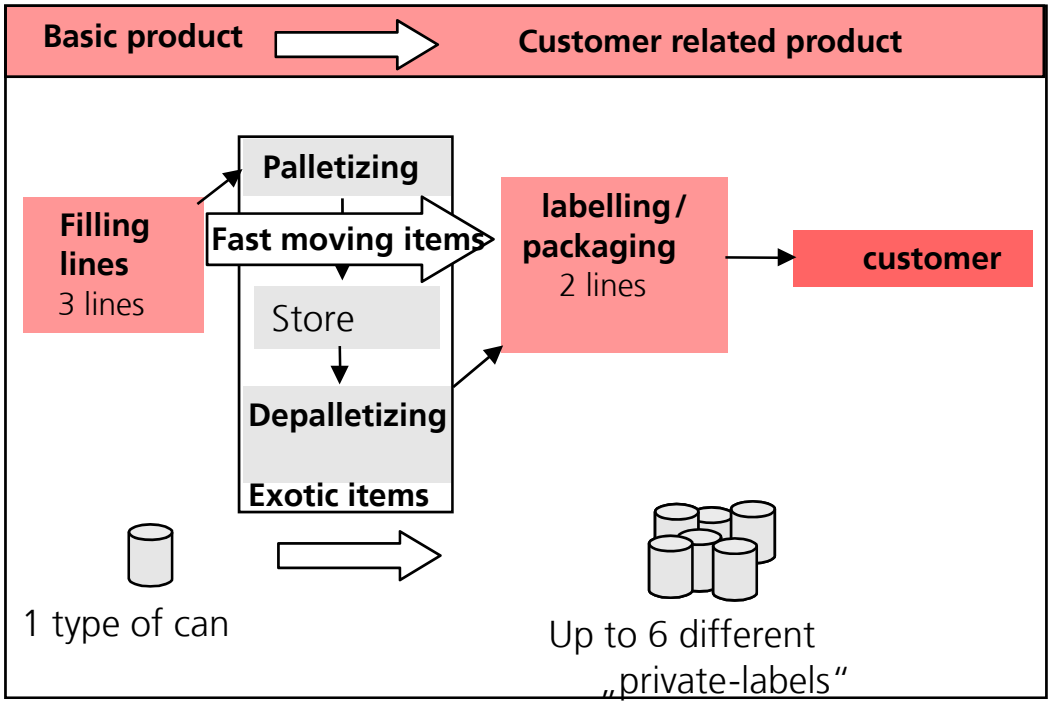
4.1 To cope with product variants (3)

Possible solutions



4.1 To cope with product variants (4)

Examples from industry: production of blank cans of soups



Production volume:
app. 100 mio. units p.y.
Line output:
app. 500 cans/min.

Decision concerning blank can production due to higher flexibility and less investment

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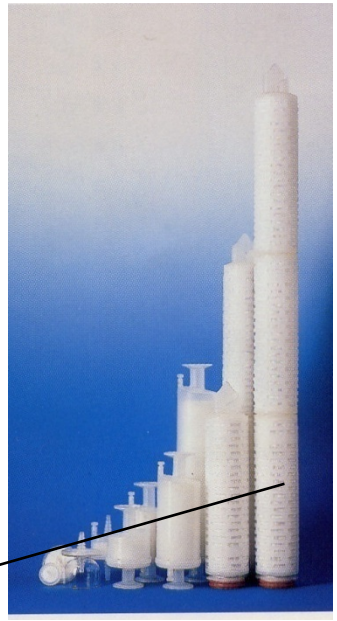
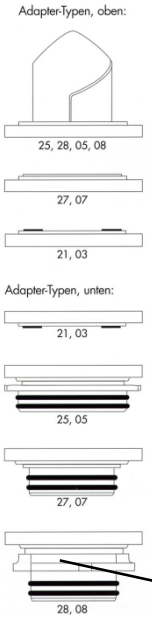
4.1 To cope with product variants (5)

Examples from industry: to cope with product variants by modular products (basic product + different connection adapters) and cellular manufacturing at a producer of filters





Example: filter cartridge made of three 10" basic cartridges

Connection adapters

Example:
by combination of 10"- basic filter cartridges with
- different connection adapters,
- multiple cartridges,
- various packings
the entire variety of customer specific products are derived.

The range of final products is < 10.000 and shows a typical ABC-characteristics. The number of individual products is between <50 p.y. up to more than 10.000.

The production structure is organized as cellular manufacturing (cartridge-/connection adapter cells) and a manufacturing cell for exotic items.

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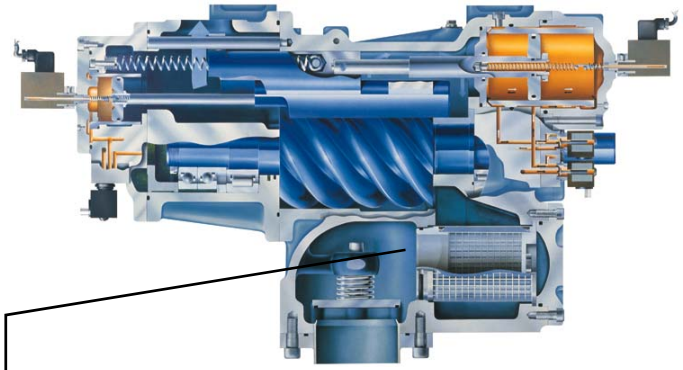
4.1 To cope with product variants (6)

Examples from industry: coping with variants by latest point of configuration – example screw compressors (source: GEA Grasso GmbH, Berlin)



This is the part, that makes the screw compressor a customer related solution by defined form elements

The entire manufacturing process is customer neutral. The specific parts, that make a customer related solution are produced together with the compressor's case.

For a specific customer order the related parts are milled right before the final assembly.

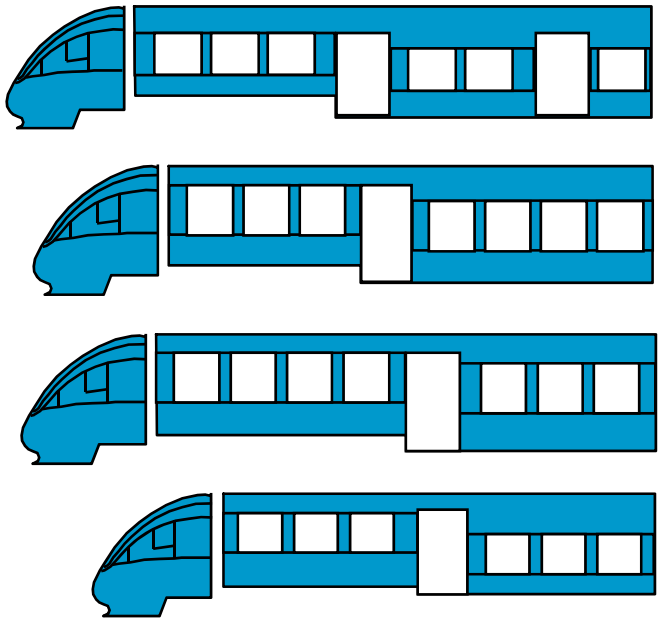
Benefits:

- Customer neutral manufacturing. The throughput time has no impact on the delivery time.

- Possibility to assemble a customer related compressor from a very limited number of parts.

4.1 To cope with product variants (7)

Examles from industry: building blocks for a familiy of rail vehicles



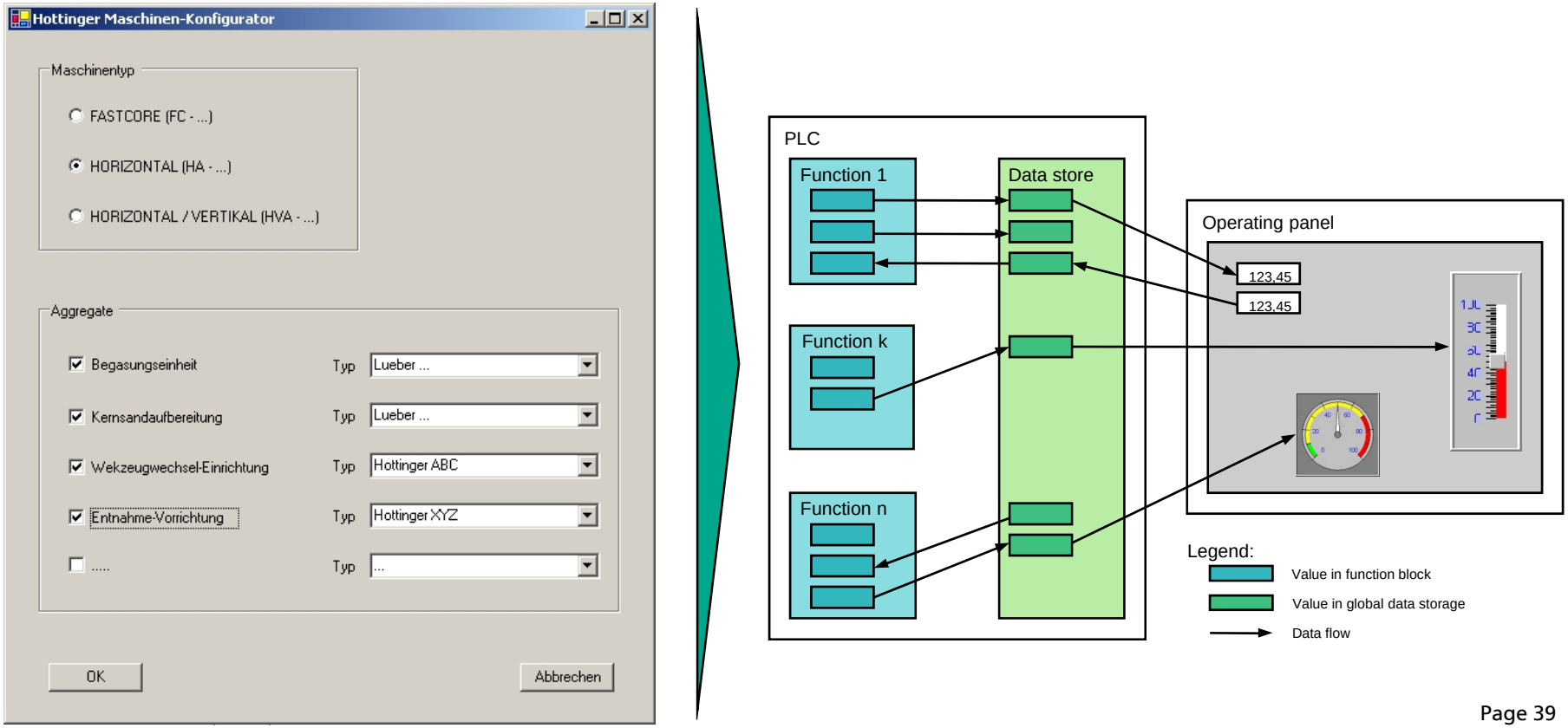
One train - x variants

Goal of the project:
80% of all customer orders should be fulfilled with standard components, such as air condition, doors, brake systems, etc.

Steps:
- **Define a generic product: what is equal with all sold vehicles?**
- **Define components that can be assembled to this generic product**
- **Define customer related features that may be added to the generic product, such as width o window, width of seats, number of doors, entrance height, engine concept, etc.**
- **Define components that fit to the customer related features.**

4.1 To cope with product variants (8)

Examples from industry: machine configurator and support of PLC-programming and machine visualization



Extension 2:

Lean manufacturing: simplify your factory

4.2 Lean manufacturing: simplify your factory (1)

Definition

To react flexibly to customers needs

1. Internal flexibility
= to be able to produce customer related products ➔ to cope with products variants (see 3.1)
= to quickly adapt facilities to new products/new orders ➔ facility planning
= to flexibly react to changes concerning the product's configuration ➔ manufacturing control
= to react to unleveled customer demands ➔ manufacturing control
= to adapt the factory to new processes and organizational changes

2. External flexibility
= to efficiently shape value creating networks

4.2 Lean manufacturing: simplify your factory (2)

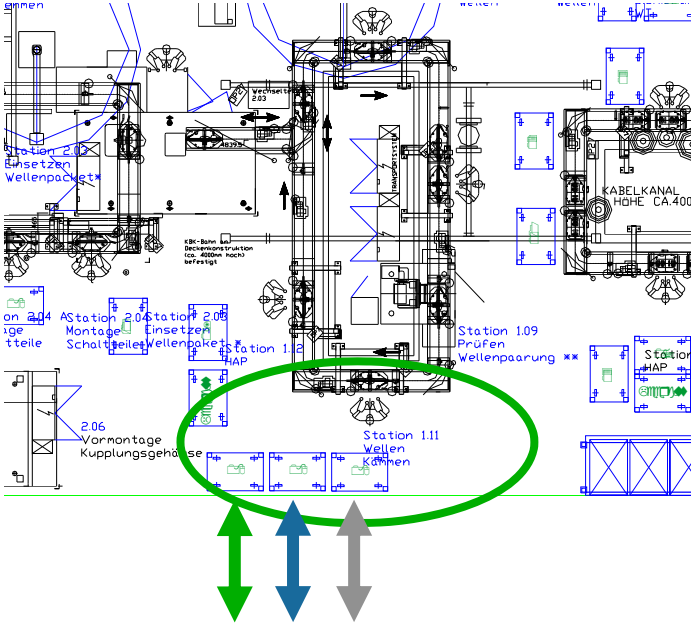
Features of a continuous process flow:

- **Produce in the customer's cycle time: the ideal manufacturing line produces according to its customer's cycle or according to the customer's call-off**
- **One-piece flow: single process steps must be as close as possible in a process flow and should be synchronized**
- **PULL-system: if it's not possible to shape a continuous flow, the most efficient material flow is a PULL-System, connecting process steps throughout the value adding chain**
- **Control of only one process step: this pacemaker-process is directly 'controlled' by the customer demand**
- **Constant PULL of small units: use small load carriers instead of large wire metal boxes; reduce range of coverage and provide the line continuously by milk runs (example see next page)**

4.2 Lean manufacturing: simplify your factory (3)

Features of a continuous process flow:

- **Constant PULL of small units: use small load carriers instead of large wire metal boxes**



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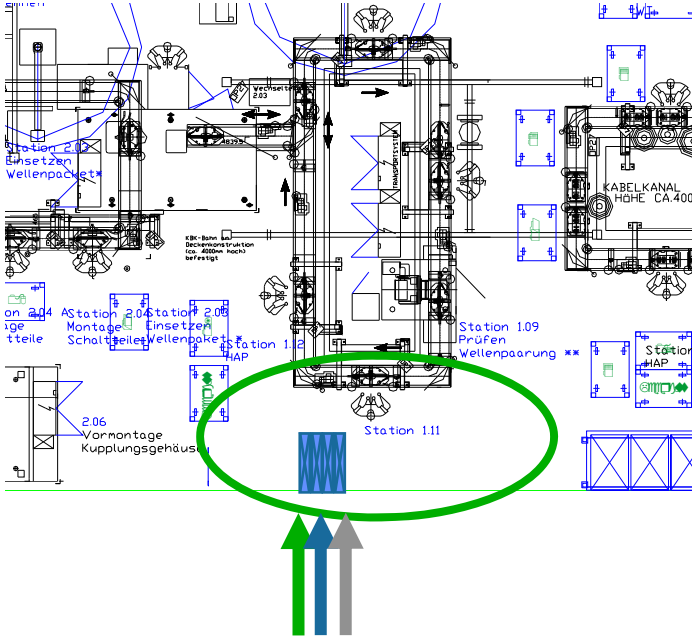

Permanent exchange of wire metal boxes

Continuous provision with small carriers

- Space for material provision reduced by app. 60 %
- range of coverage reduced from 3 shift to 2 hours!

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4.2 Lean manufacturing: simplify your factory (4)

Examples from industry: set-up flexible processes in an engine plant

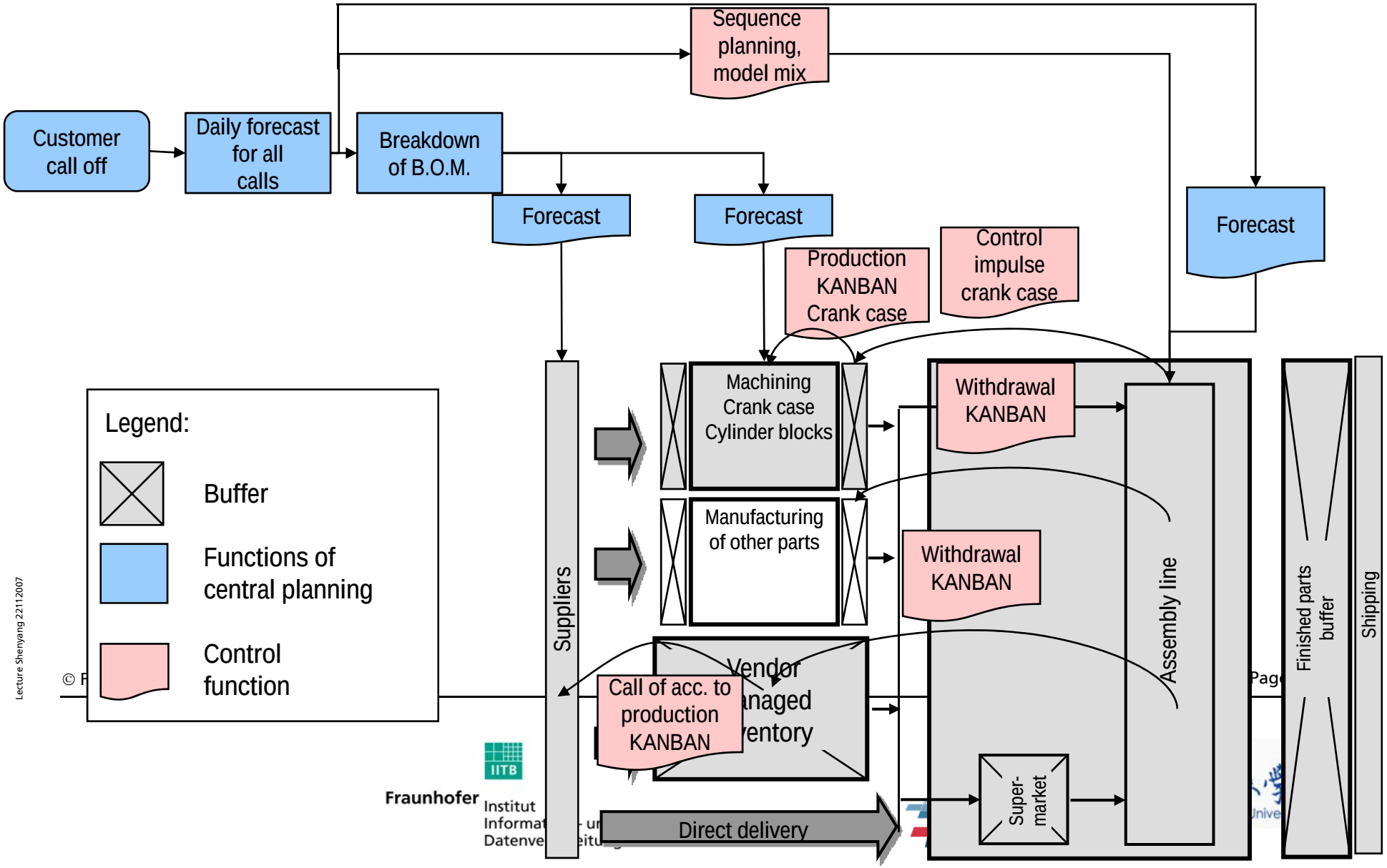
Foto: IWKA

Number of engines: 250.000 engines p.y.
Cycle time: app. 60 sec.
Lot size final assembly: 1
Lot size machining : 1 or capacity of one pallet
Number of engine variants: app. 20

The requirements of the engine manufacturer have been set up in a way that it now is possible to produce any kind of engine variant according to the customer demands without extra setup time for machines.

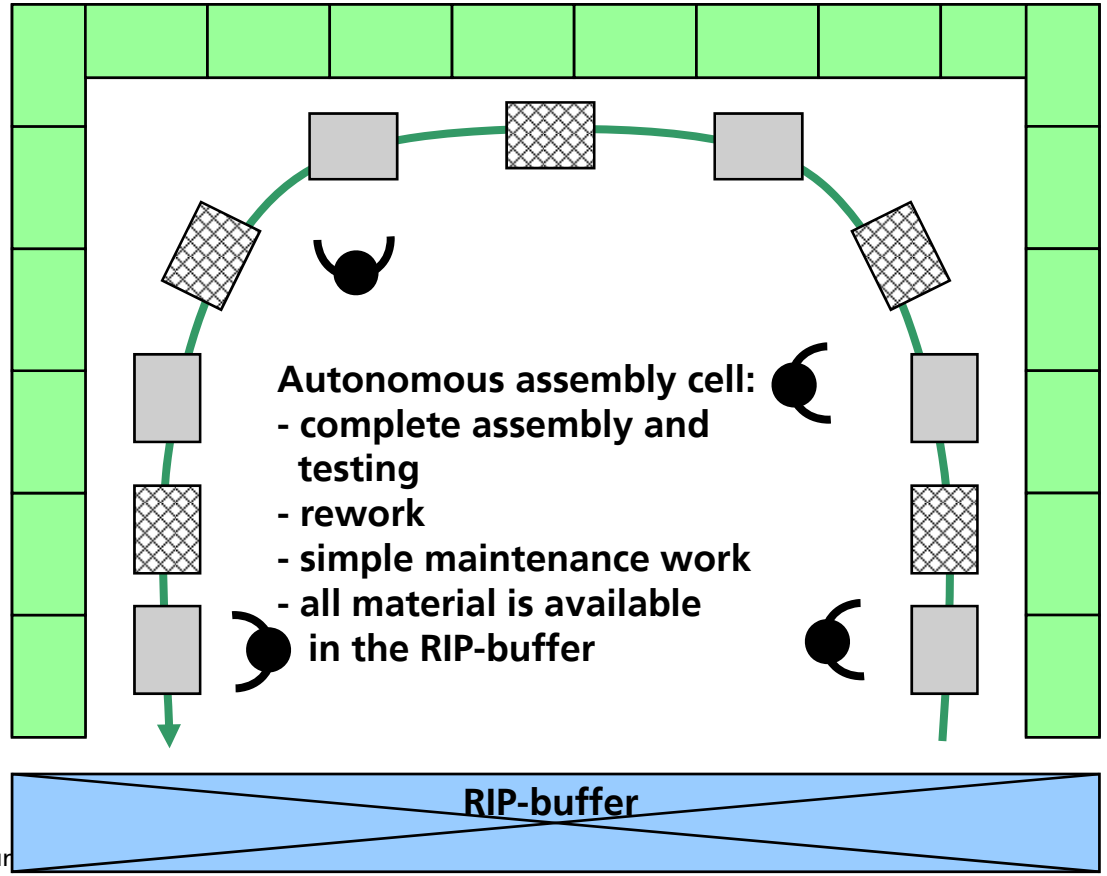
Benefits:
- **maximum flexibility concerning variants**
- **minimum stock of finished engines**
- **low work-in-process**
- **high adaptivity to unexpected changes**

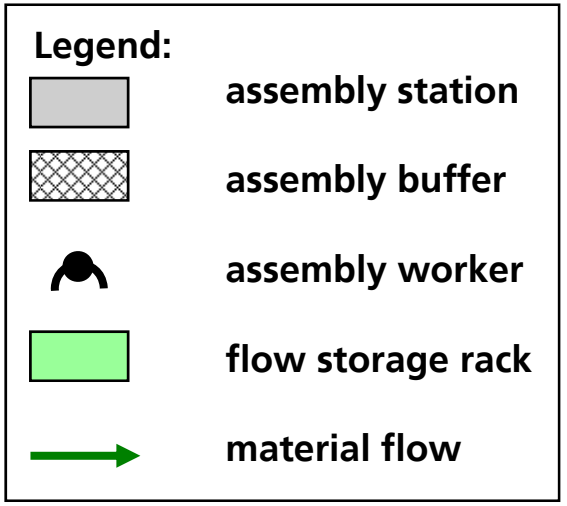
4.2 Lean manufacturing: simplify your factory (5)



4.2 Lean manufacturing: simplify your factory (6)

Examples from industry: demand oriented control at a producer of brake systems for commercial vehicles





4.2 Lean manufacturing: simplify your factory (7)

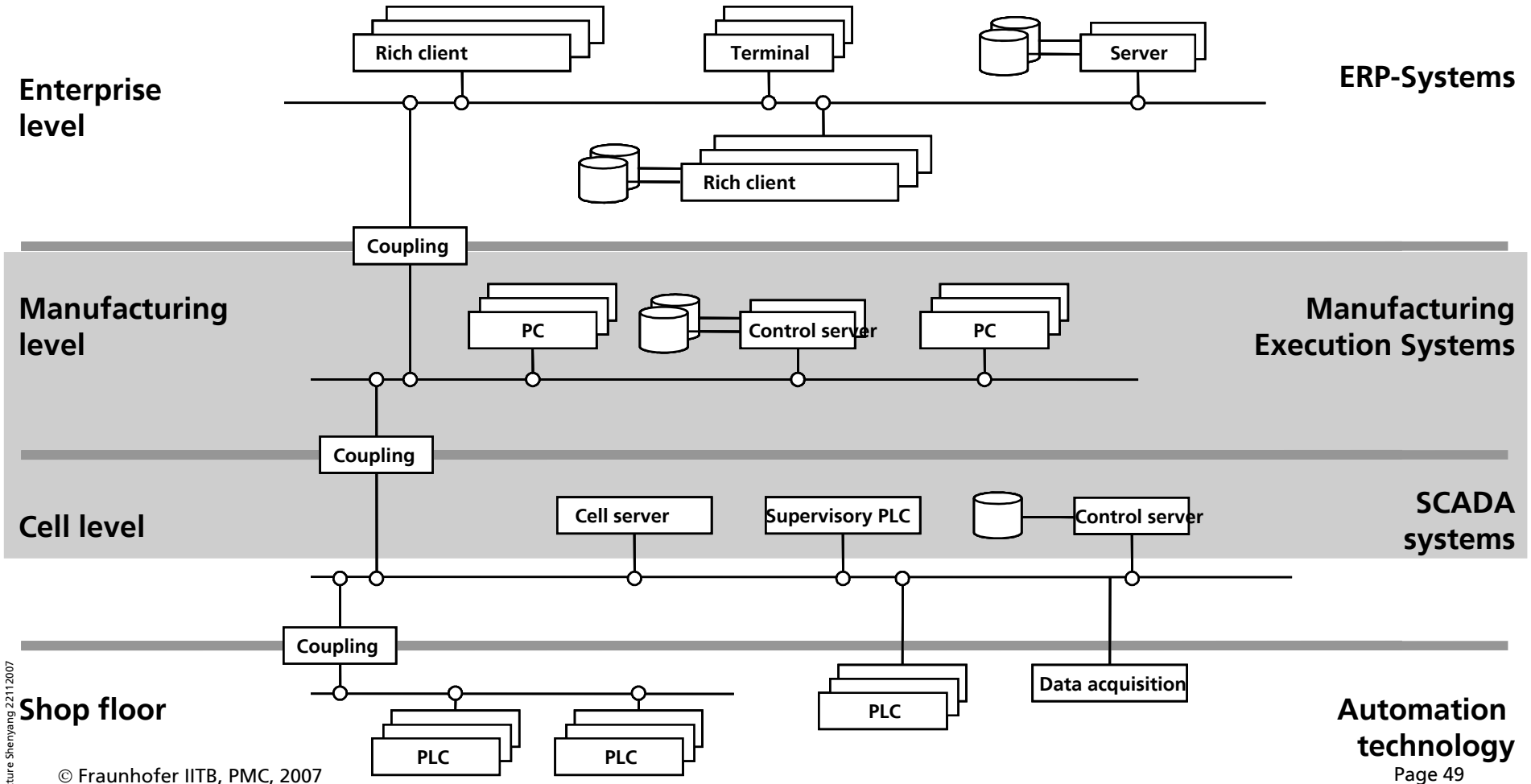
Examples from industry: demand oriented control at a producer of brake systems for commercial vehicles

Source: Wabco, braking systems for commercial vehicles

5. Systems supporting production planning, monitoring & control:

Manufacturing Execution Systems (MES)

5. Manufacturing Execution Systems in a factory's IT hierarchy (Source: Betriebshütte, VDI 5600)



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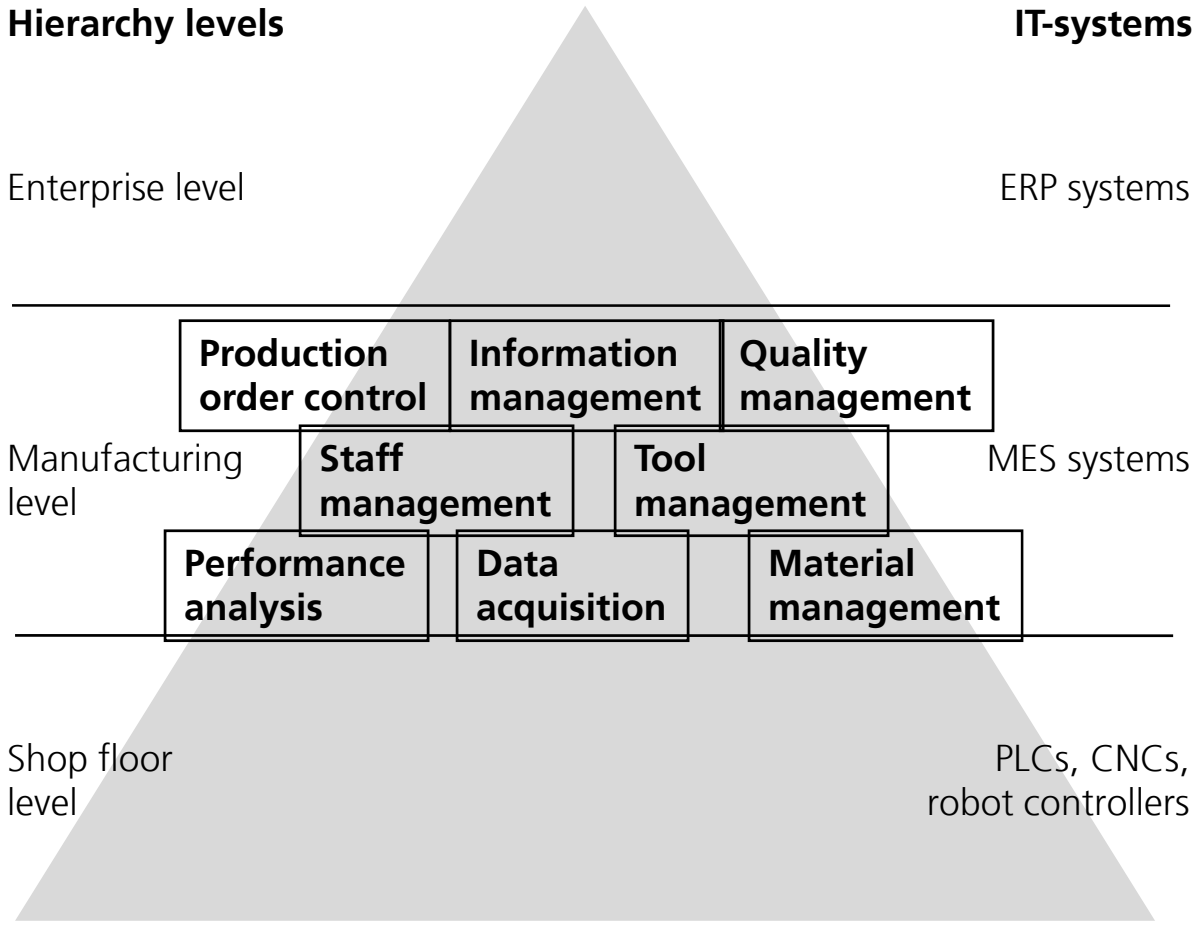
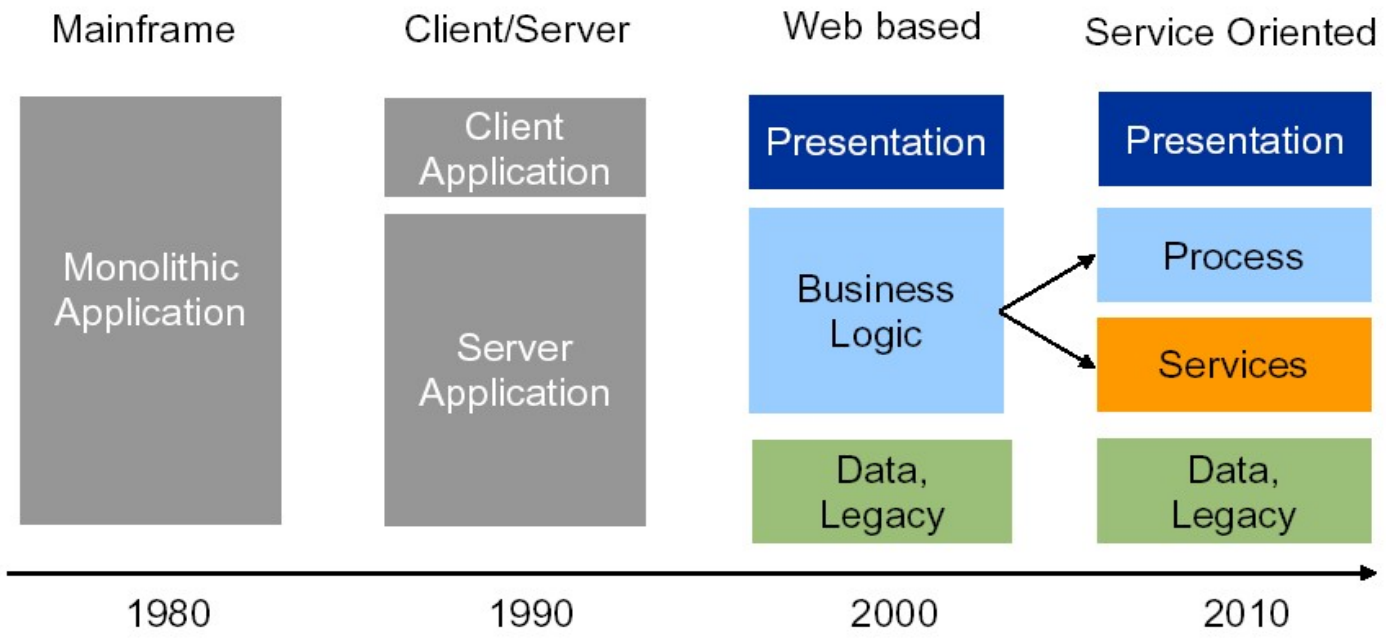
5. Tasks covered by today's manufacturing execution systems (Source: VDI 5600)



5. Typical time horizons and items within the various control levels of an enterprise (Source: VDI 5600)

	Time horizon	Time pattern	Item
Enterprise level	One or more days / shifts	Some weeks / months	Entire pool of orders
Manu-facturing level	Some seconds up to one shift	One or more shifts	One or more orders
Shop floor level	Milliseconds up to seconds	Seconds up to some minutes	Single process steps

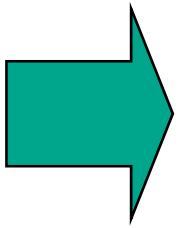
5. Architecture of today's and tomorrow's MES-systems



5. Requirements for production systems

- Facilities survive products, e.g. commercial vehicles 20 years (spare parts)
- PLCs and other controls have to run in changing environment
- Number of products variants increases in many branches
- High variety of controls, software versions and super-ordinate IT-systems

See:
Wiendahl, H.-P. et. al.: Changeable Manufacturing - Classification, Design and Operation. Key note paper at the CIRP General Assembly, August 2007; Annals of the CIRP, 2007.



Flexible configuration of production lines during running operations; when facilities are changed , software must be adapted as well

Scope for tomorrow morning

1. **Some general remarks on automation**

2. **Automotive manufacturing**

3. **Manufacturing execution systems for automotive production**
   - **example for a successful production monitoring system**
   - **general aspects of sequencing**
   - **integration of MES-components**
   - **central visualization and control room concept**
   - **integration of MES with digital factory**

Thank you for your attention!

Imprint

Systems for Production Control and Production Planning

- Lecture on manufacturing and its IT-systems –

Shenyang, November 22, 2007

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