Trends and Concepts of Business Application Architecture

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Enterprise Platform and Integration Concepts
Hasso-Plattner-Institut

Course Overview

Trends and Concepts of Business Application Architecture

- Digitalization of Business Processes
- Enterprise Resource Planning
  - Sales and Distribution
  - Finance, Accounting, and Controlling
  - Human Resources
  - **Material Management and Production Planning**
- In-Memory Databases for Business Applications
- Customer Relationship Management
- Enterprise Cloud Platforms for Integration and Extensions
- Block Week: Architecture Deep Dives

Material Management and Production Planning
- Basic Concepts
- Examples from SAP S/4 HANA Sourcing, Procurement and Supply Chain

Werner Sinzig

June 2022

Agenda

1. **Flow of Goods and Values**
2. Master Data

   Material, Bill of Material, Routing, Product Cost Calculation
3. Procurement

   Strategic Purchasing, Operational Purchasing
4. Warehouse

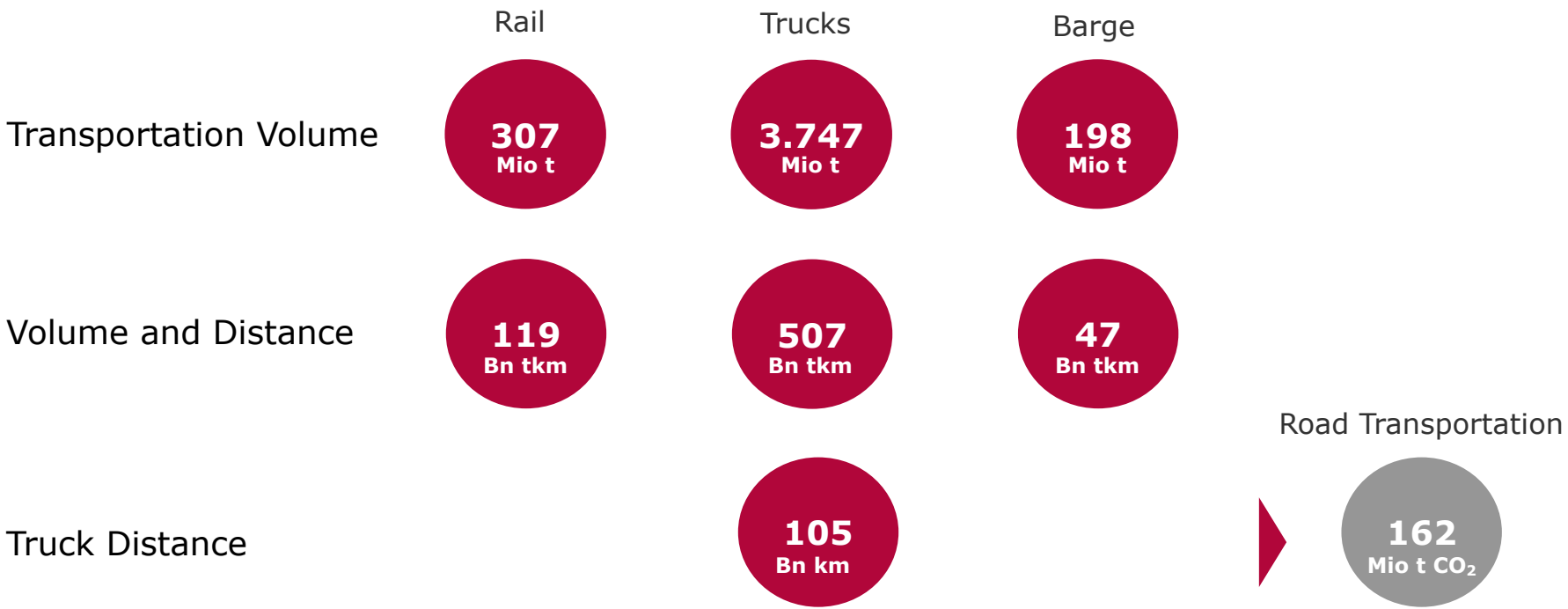
   Disposition Types, Consumption Forecast
5. Production

   Integrated Production Planning, Manufacturing

Appendix

Flow of Goods and Values

Volume Numbers: Goods Traffic in Germany in 2018



Sources: Stat. Bundesamt, Kraftfahrtbundesamt, Umweltbundesamt

Flow of Goods and Values

Flow of Values between Economic Sectors [1)]

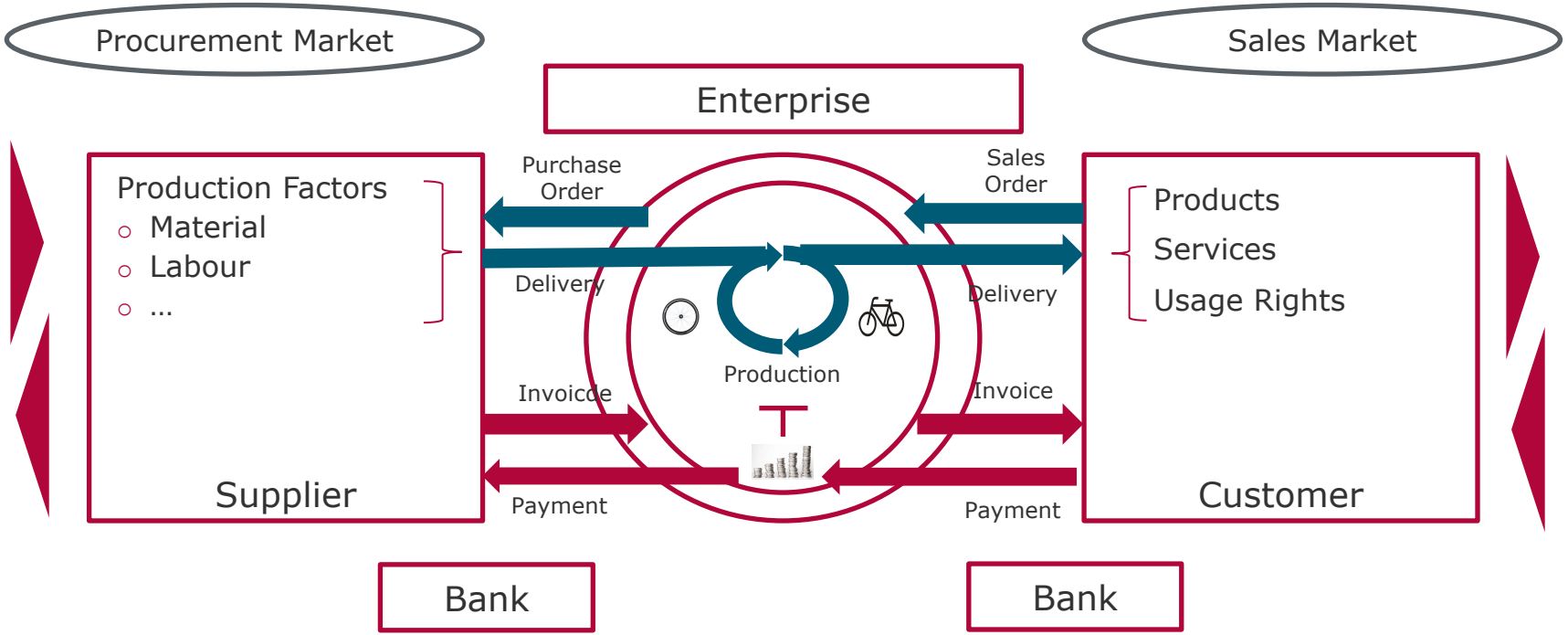
Usage / Source 2)	Input from Production Sectors			Last Usage	
	Primary Sector	Secundary Sector	Tertiary Sector	Consumption / Investment / Export	Total Usage
Primary Sector 3)	9,5	47,1	3,5	37,3	97,4
Secundary Sector 4)	11,3	1149,8	254,3	2063,4	3478,8
Tertiary Sector 5)	14,6	481,5	1179,9	2166,6	3842,6
Sources / Usage at Production Cost	35,4	1678,4	1437,7	4267,3	7418,8

Total value of goods and services

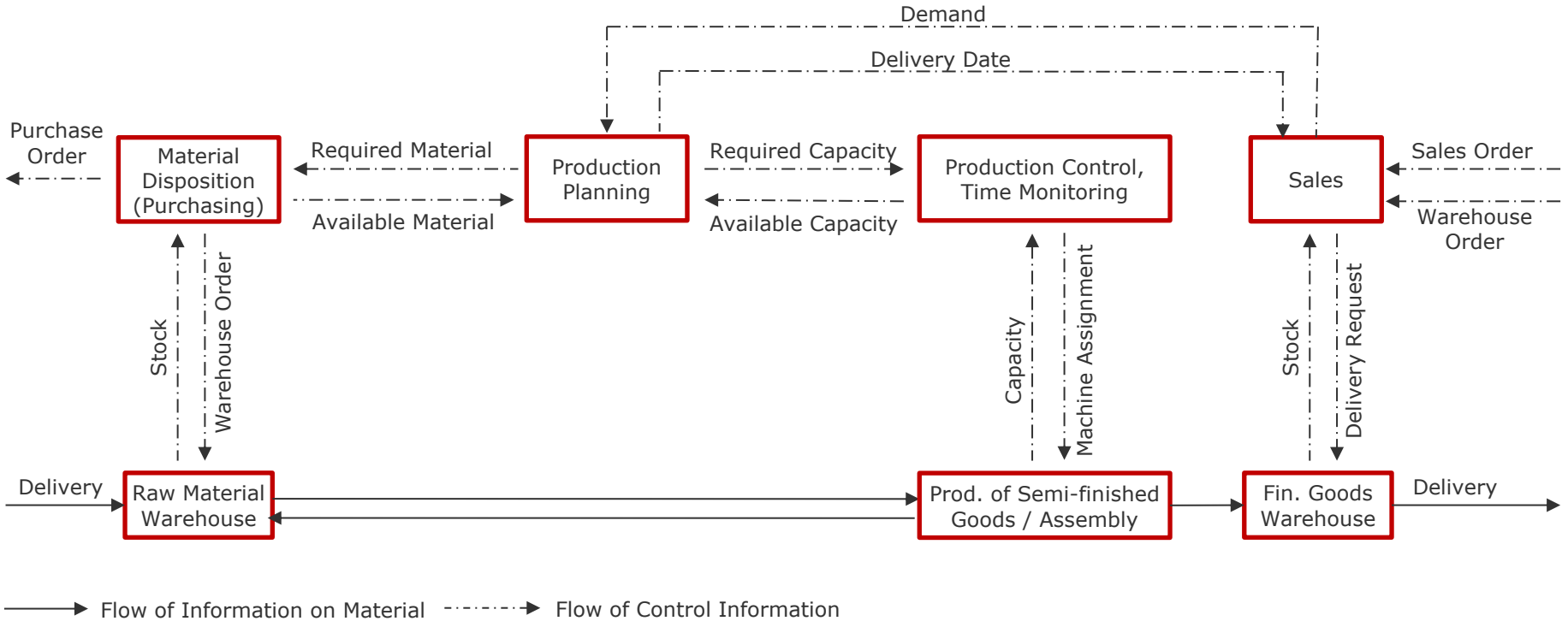
Legend:

1) Data from 2019 in Mrd. € / Source: Statistisches Bundesamt
2) Goods from domestic production and imports
3) Primary sector: agriculture and forestry, fishing
4) Secondary sector: production industry
5) Tertiary Sector: private and public services

Flow of Goods and Values
Inside an Enterprise



Flow of Goods and Values
Inside Production



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Appendix

Master Data: Material
Definition, Synonyms and Generalizations

- Manufacturing Industry → *material*
  - with *part* as synonym
  - with *raw material*, *semi-finished product* and *finished product* as specialized terms
  - with *product* as general term for *semi-finished* and *finished product* and *trade good*
  - with *good* as a general term for *raw material* and *trade goods*
- Retail industry → *article*
  - with *consumer good / consumer product* as a synonym for *article*
- Banking, insurance industry → *product*
- Service industry → *service*
- Business administration / economics → goods

Master Data: Material
Identification (1/2)

By industry thousands of materials are purchased, produced, stored and sold. A material may exist in multiple variants. Materials occur in most main processes.

Materials need to be efficiently identified. Various coding methods exist.

- incremental numbering ➡ ID 4711
- descriptive codes (‘smart codes’) ➡ ID MntBike
- descriptive codes combined with suffix for variants ➡ ID MntBike-Children
- hierarchical categorization schemes (eg. hierarchical sales groups)

1	Mountain Bike		
	1	Model	
		1	Men
		2	Women
		3	Children
	2	Colour	
		1	Blue metallic
		2	White
		3	Black matt

Product	Sales Group	Model	Sales Group	Colour	ID
1	1	1	2	1	4711
1	1	1	2	3	4712
1	1	3	2	1	4713
1	1	3	2	2	4714

Master Data: Material
Identification (2/2)

- Multidimensional categorization schemes (a.k.a. material classes)
  - For a combination of sales groups more than one material may exist. To manage this a material class management system was developed.
  - For all fields of the material master data table classes of allowed entities can be defined.
  - When a new material master record needs to be created existing records are checked with a multidimensional key from all classes.
  - When a new material master record needs to be created a similar one may be used as reference. The identifier is an incremental number.
  - In all business processes material records can be selected by the multidimensional material classes.

Master Data: Bill of Material
Definitions

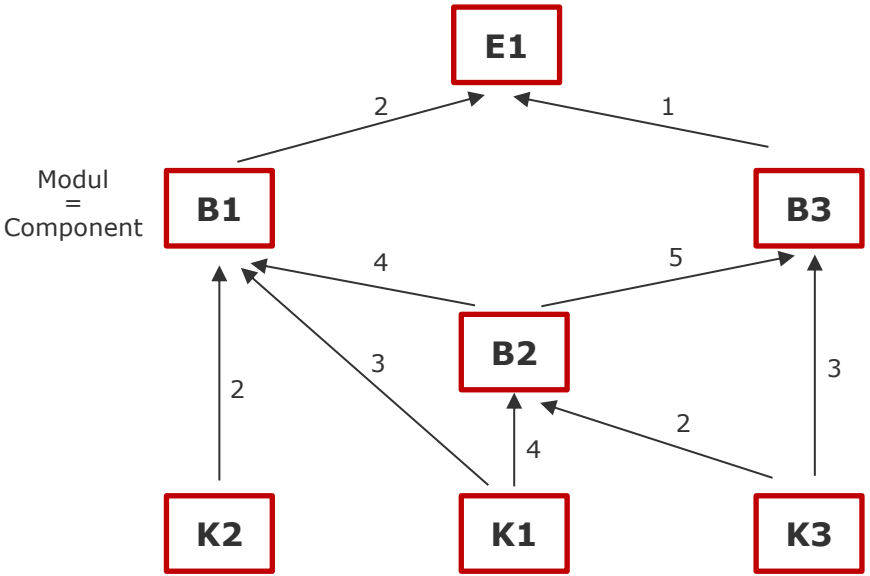
To produce finished goods in most cases several materials are needed. The composition of finished goods is described in the bill of material (BOM) (synonym in chemical industry is recipe). Bills of materials are used in departments like construction, production planning, assembly, standardization, and product cost calculation.

Usually bill of materials are multilevel, that means a finished good consists of materials which themselves consist of other materials. In a multilevel bill of material the upper material is called a module. The material which goes into a module is called a component. Modules and components are identified by their material number.

An edge in a bill of material defines how many units of component are needed to build one unit of the module (BoM coefficient).

The Gozinto Graph is the inverse description of o BoM. It describes for a named material in which modules it is used (“it goes into”)

Master Data: Bill of Material
Structure, Presentation and Usage (1/2)

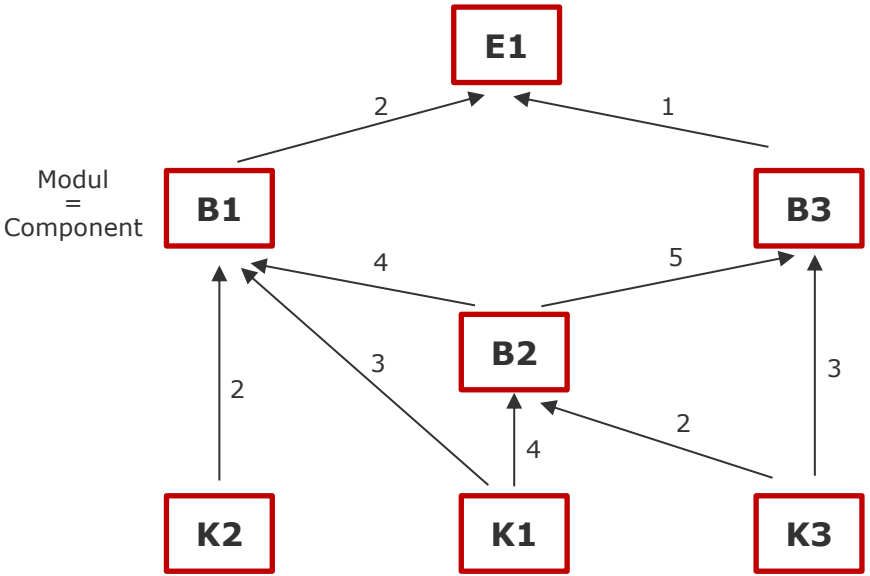


E: Finished Good B: Semi-finished Good K: Raw Material

Form of Presentation and Usage

Multi-level BoM		Singel-Level BoM	
E1	1	E1	1
B1	2	B1	2
.. K2	.. 2	B3	1
.. K1	.. 3		
.. B2	.. 4		
.... K1	 4		
.... K3	 2		
B3	1		
.. B2	.. 5		
.... K1	 4		
.... K3	 2		
.. K3	.. 3		
• Spare Parts Catalog • Product Cost Calcul.		• Requirements Planning • Operations Scheduling	

Master Data: Bill of Material
Structure, Presentation and Usage (2/2)



Form of Presentation and Usage

Overview BoM		Parts Usage	
E1	1	K1	1
B1	2	B1	19
B3	1	B2	4
K2	4	B3	20
K1	58	E1	58
B2	13		
K3	29		
• Total Parts needed		• Impact of a material bottle neck • Impact of a cost increase	

E: Finished Good B: Semi-finished Good K: Raw Material

Master Data: Routing
Definition, Structure

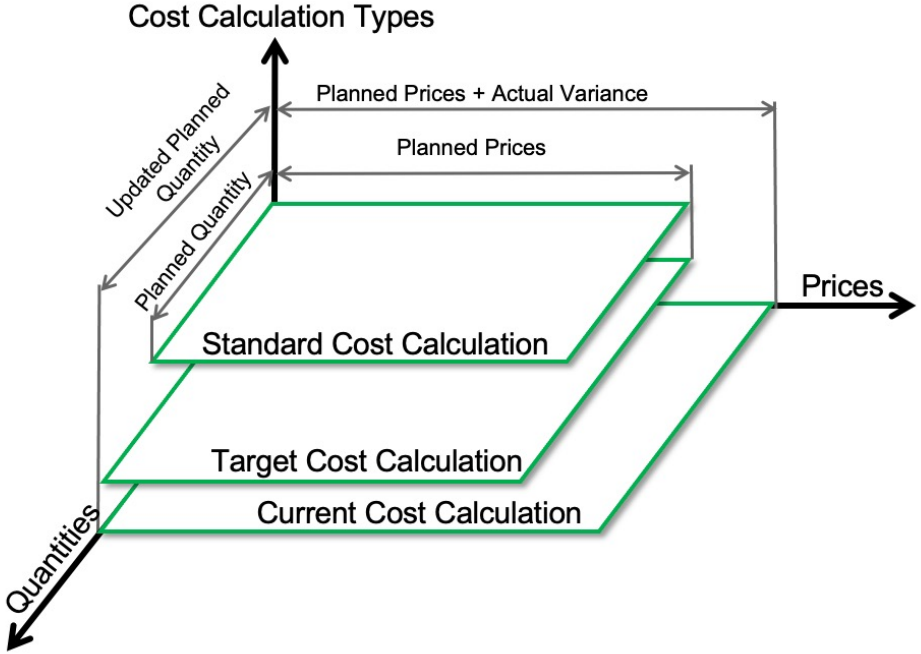
A routing (a.k.a. Bill of Operations) describes by so called work processes in which sequence resources (machines and people) are used to produce a specific lot size of a finished good or of a component.

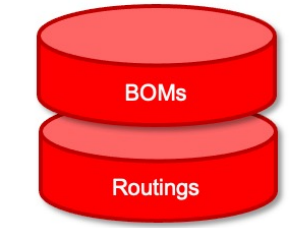
A work process step points to a cost center / activity. Here the planned time needed is stored.

Finished Good E1
Lot Size 20 Pc

Step Number	Work Process Name	Resource Cost Center / Activity	Time
1	Set up	4711 / Labour Hours	30 min
2	Turning	4711 / Machine Hours	120 min
3	Turning	4711 / Labour Hours	120 min
4	Milling	4711 / Machine Hours	60 min
5	Cleaning	4711 / Labour Hours	15 min
6	Quality Check	4799 / Labour Hours	30 min

Master Data: Product Cost Calculation
Cost Calculation Types (1/2)

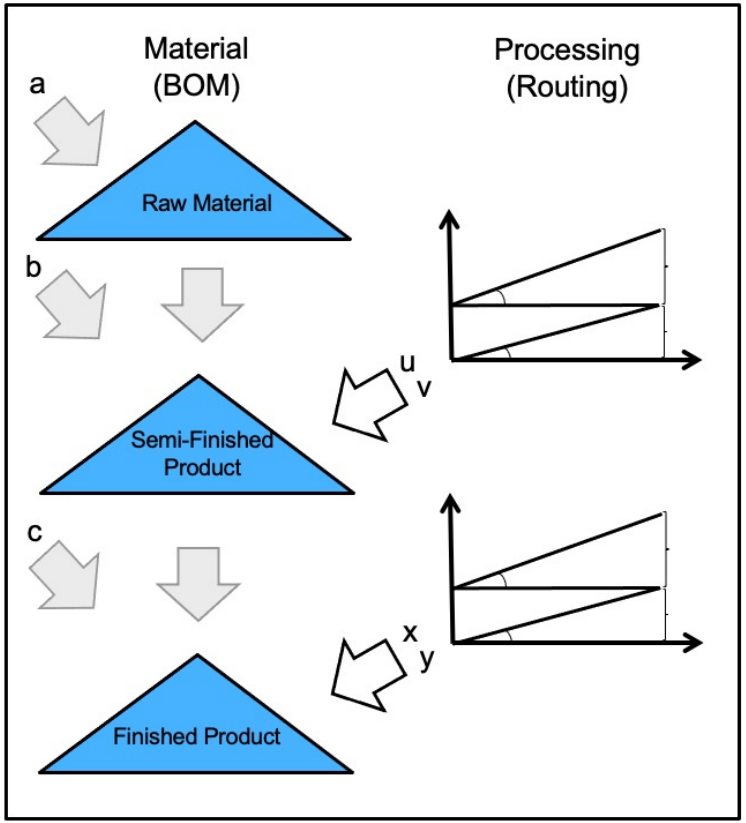




Different State of Quantity Structure

Different Valuation Strategy

Master Data: Product Cost Calculation
Calculation Logic



Manufacturing Cost Split

Material Category 1	Material Category 2	Processing var	Processing fix
a			

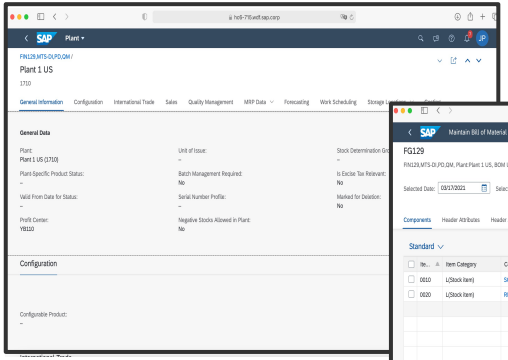
Material Category 1	Material Category 2	Processing var	Processing fix
a + b		u	v

Material Category 1	Material Category 2	Processing var	Processing fix
a + b + c		u + x	v + y

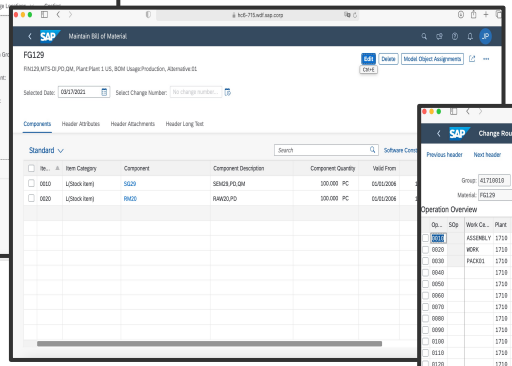
S/4 HANA Material Management Master Data

Presentation: Material, Bill of Material, Routing, Product Cost Calculation

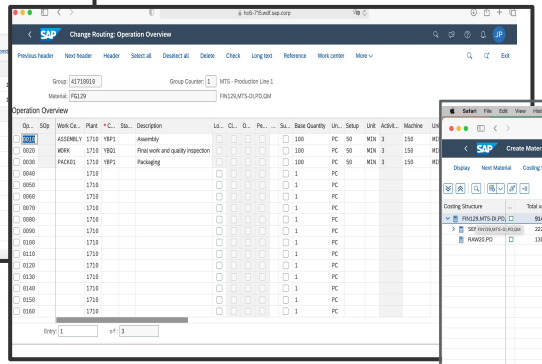
Material



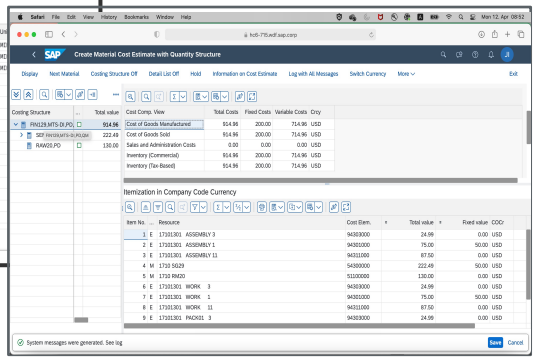
Bill of Material



Routing



Product Cost Calculation



Access to system HC6

https://hc6-715.wdf.sap.corp/ui

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4. Warehouse

   Disposition Types, Consumption Forecast
5. Production

   Integrated Production Planning, Manufacturing

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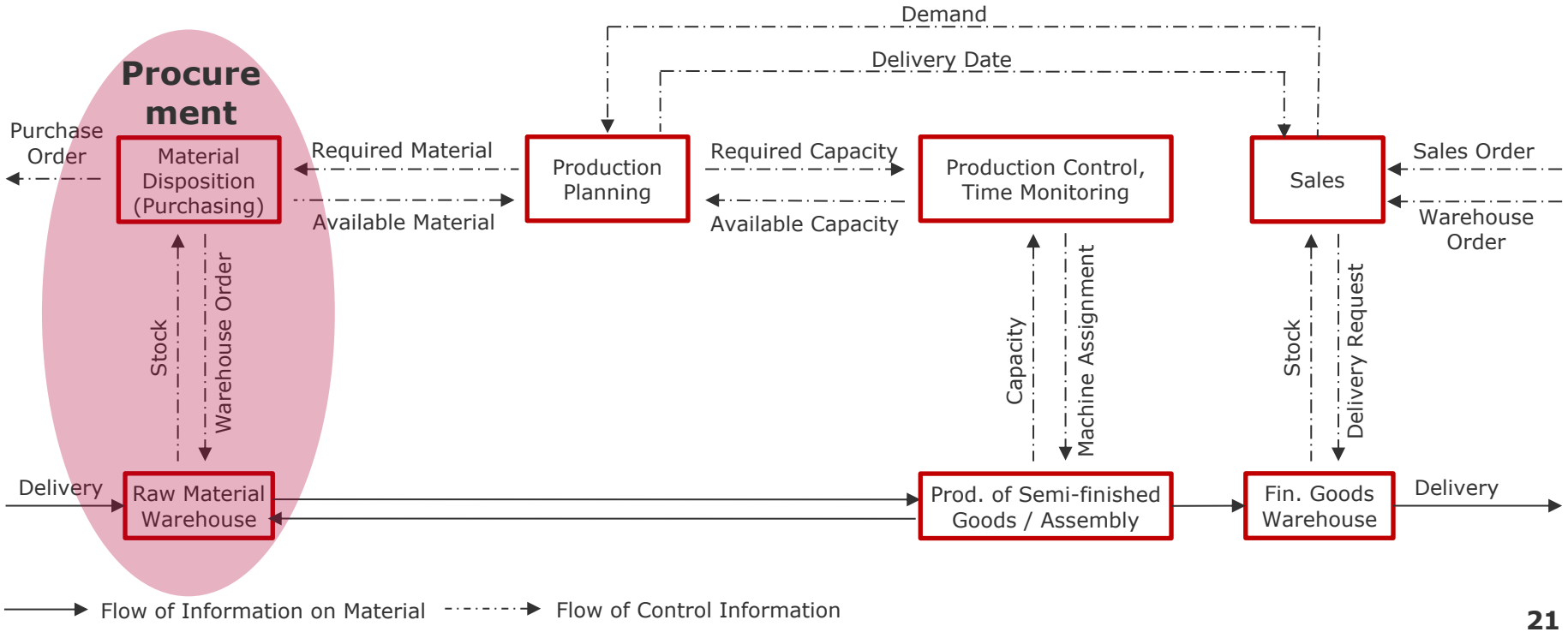
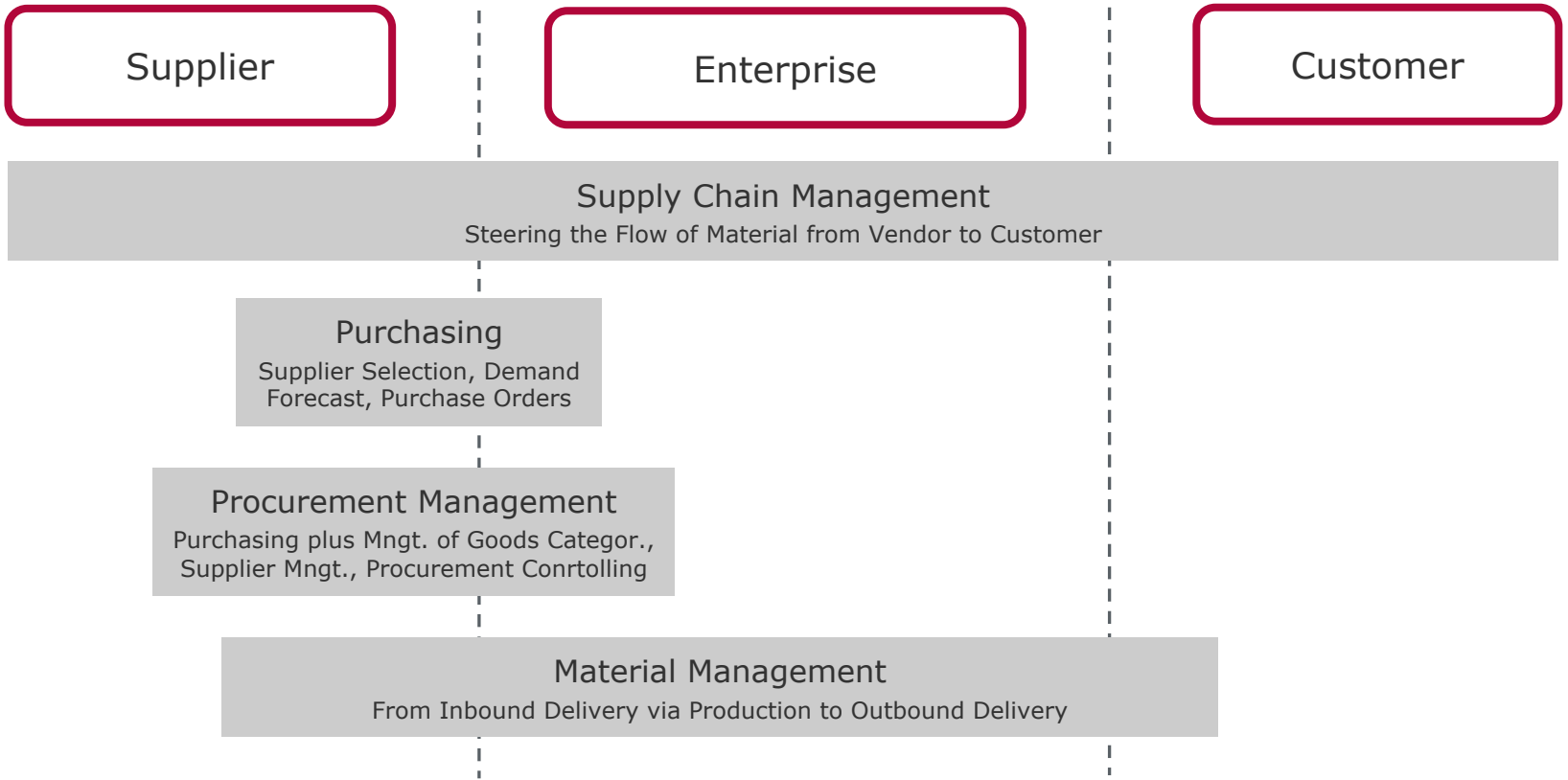
Flow of Goods and Values
Inside Production



Procurement
Responsibilities



Procurement

Procurement Objects, Portfolio of Goods Categories, Department Org.

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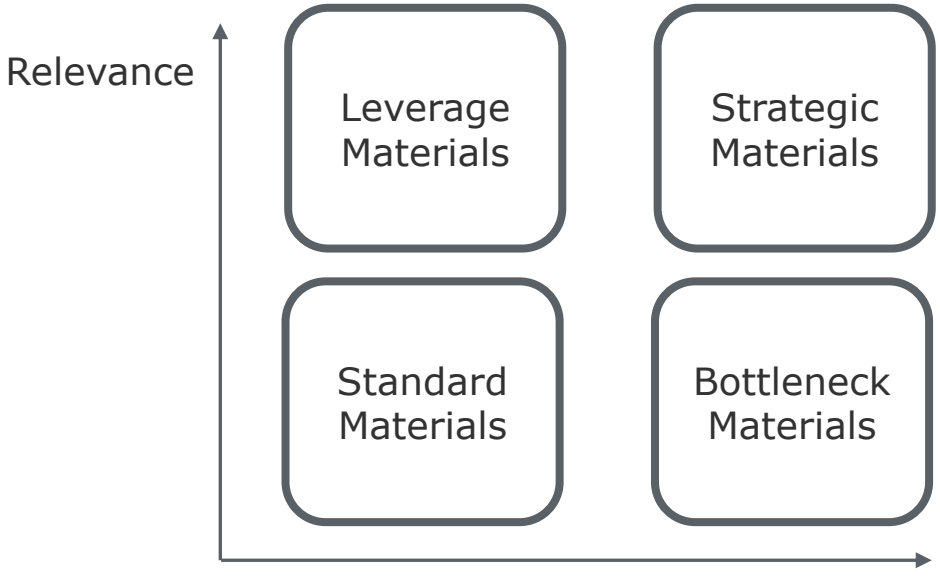
Procurement Objects

- **Direct Material**
  Raw Material, Trade Goods
- **Indirect Material**
  Assets, Services, Office Supply, Energy

Portfolio of Goods Categories

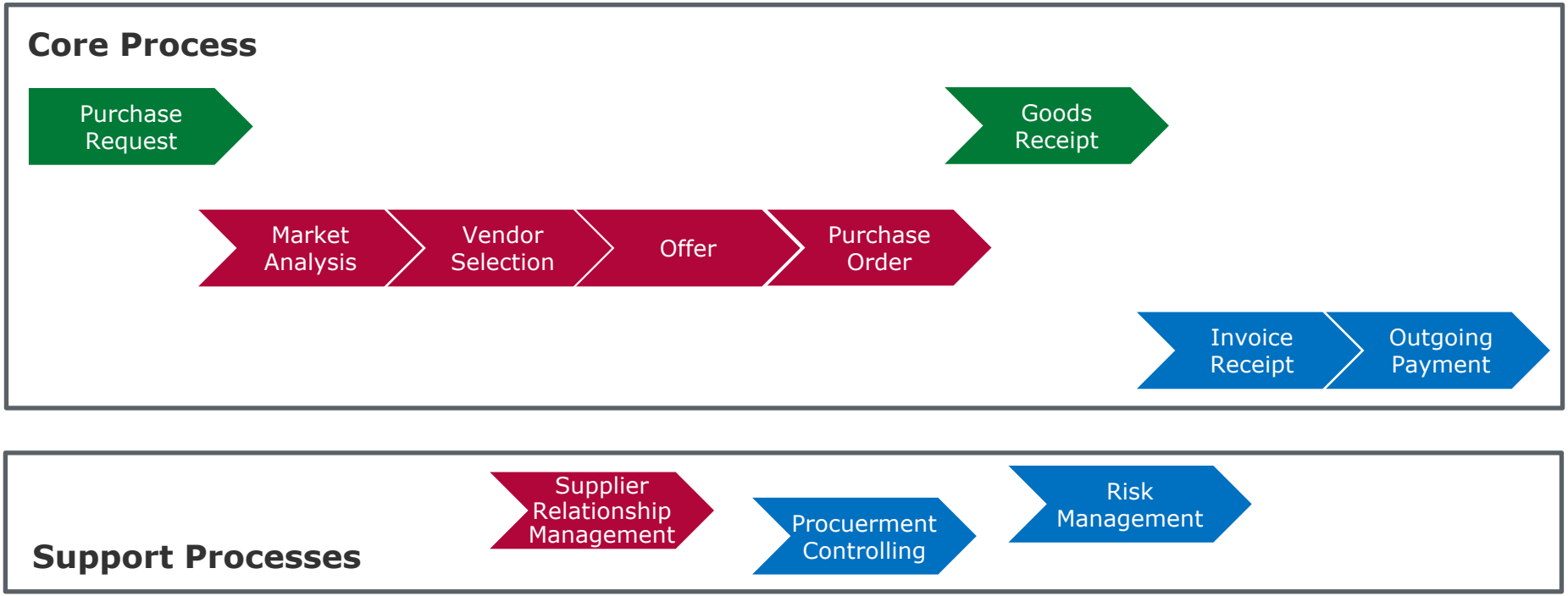


Procurement
Sourcing Strategy

Dimension	Options			Criteria
Number of Supplier	Single Sourcing	…	Multiple Sourcing	• Effort to coordinate • Dependency • Risk of Loss • Purchase Volume Advantage
Complexity of Procurement Objects	Unit Sourcing	…	System Sourcing	• Focus on Core Competencies • Vertical Integration / Production Control
Place of Procurement	Local Sourcing	…	Global Sourcing	• Transportation Costs and Risk • Price, Exchange Rate • Supplier Relationship Management

https://www.koinnM-bmwi.de/fileadmin/user_upload/publikationen/Grundlagen_des_Einkaufs.pdf

Procurement
Procurement Process (Source to Pay)



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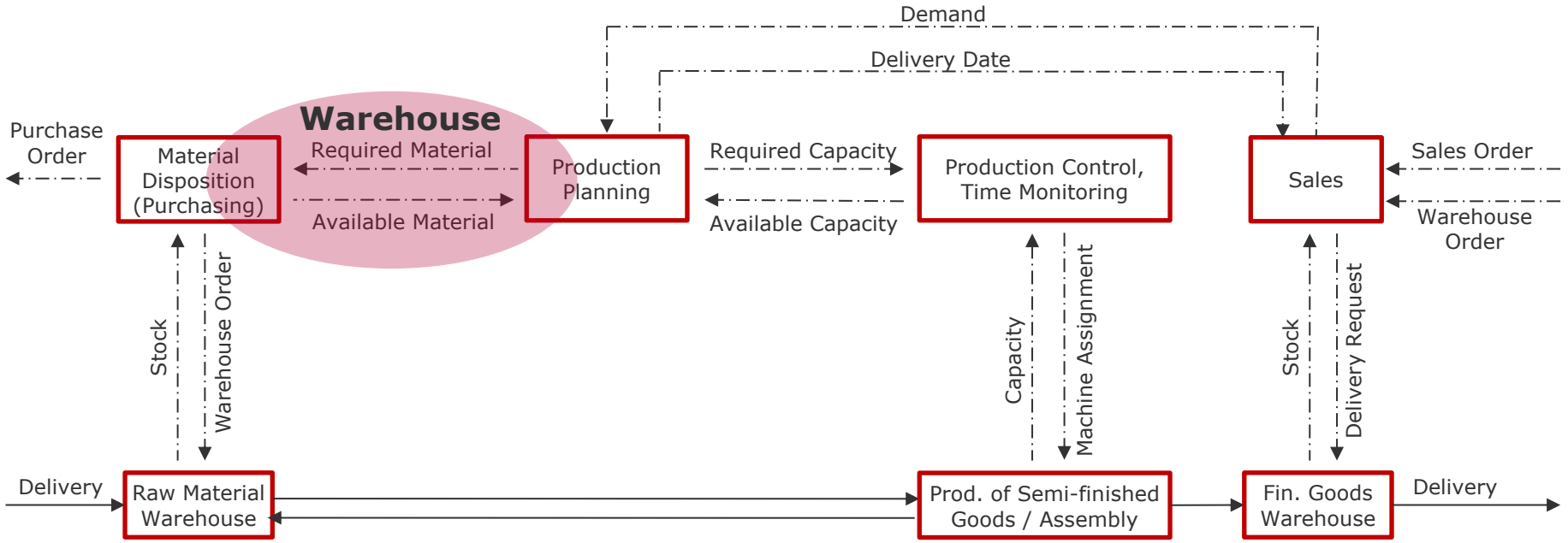


Warehouse
Tasks (1/2)

Which goods need to be stored?	At which locations?
Consumable goods	
▪ Raw material, aux. material, operating supply	Close to production site (Plant)
▪ Semi finished products and finished products	Close to production site (Plant)
▪ Work in process	On production site (Plant)
▪ Products and trade goods	Close to the customer (Distribution Center)
▪ Not-production related material eg. office supply	Rather at centralized locations
Capital goods	
▪ Physical capital goods eg. IT equipment	Rather at centralized locations
▪ Immaterial capital goods eg. money on accounts, shares, accounts receivables / payables	./.

Warehouse
Tasks (2/2)

Why are goods stored?

- Buffering: Buffering between the stream of receipts and issues of the material. Either inflow or outflow happen continually / discontinually.
- Reliability: Protect pre- and post processes from disruptions of inflow or outflow of material.
- Economy: Flexibility to buy material under favorable market conditions for profitability reasons.

Just-in-Time is a logistics method working without warehousing. The benefits from warehousing inventory are sacrificed in favor of minimizing working capital.

Warehouse
Material Requirements Planning (MRP), based on previous consumption

Exponential Smoothing

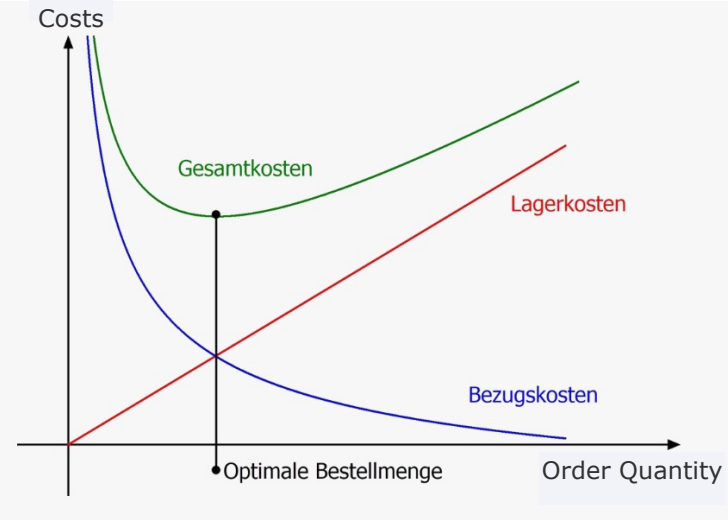
Calculation of forecast values

- Consumption-oriented MRP is based on historical values (time series).
- Forecast values are calculated as weighted averages from historical values.
- Recent values are weighted higher than older ones.
- Weighting factors decrease exponentially by time.

Assumptions

- No trends.
- Statistical independence among the historical data.

Optimal Purchase Order Quantity



Calculation of optimal Purchase Order Quantity

m = demand of a year
E = quantity indep. purchase cost / purchase order
p = interest rate for capital invested
s = price per case, quantity dependent storage cost
x = (optimal) purchase order quantity
K = total cost per year

$K = E * m / x + (p / 100) * s * x / 2$

==> Optimal purchase order quantity

$x_{opt} = (2 * m * E)^{1/2}$

Assumptions

- No fluctuate demand
- No discounts, no price jumps
- Material delivery at one point in time

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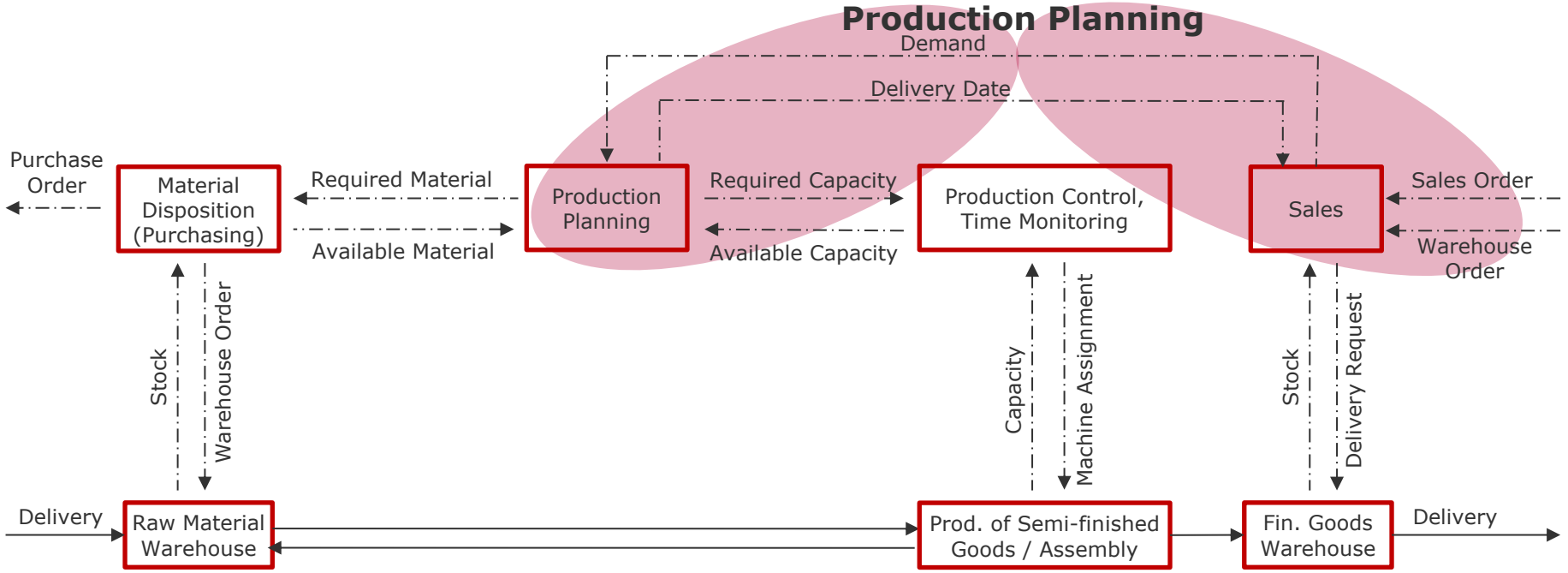
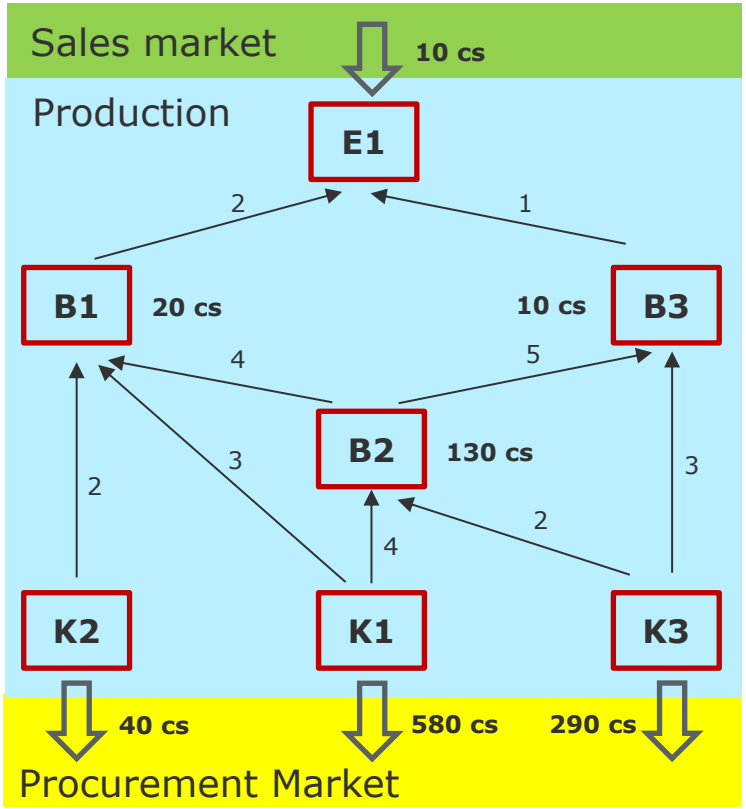


Production
Types of Organization

- Types of production
  - Engineer-to-order production: one single item
  - Repetitive production: numerous items (lot)
  - Mass production: unlimited number of items
  - Batch manufacturing: numerous, not-identifiable items
  - Joint-product production: split production
- Types of production organization
  - Order-related production: centralized by types of machines
  - Line production: centralized by groups of products
- Reference to customer order
  - Make-to-stock production
  - Make-to-order production

Different requirements regarding data model and functionality

Produktion
Material Requirements Planning (MRP), based on sales program (1/4)



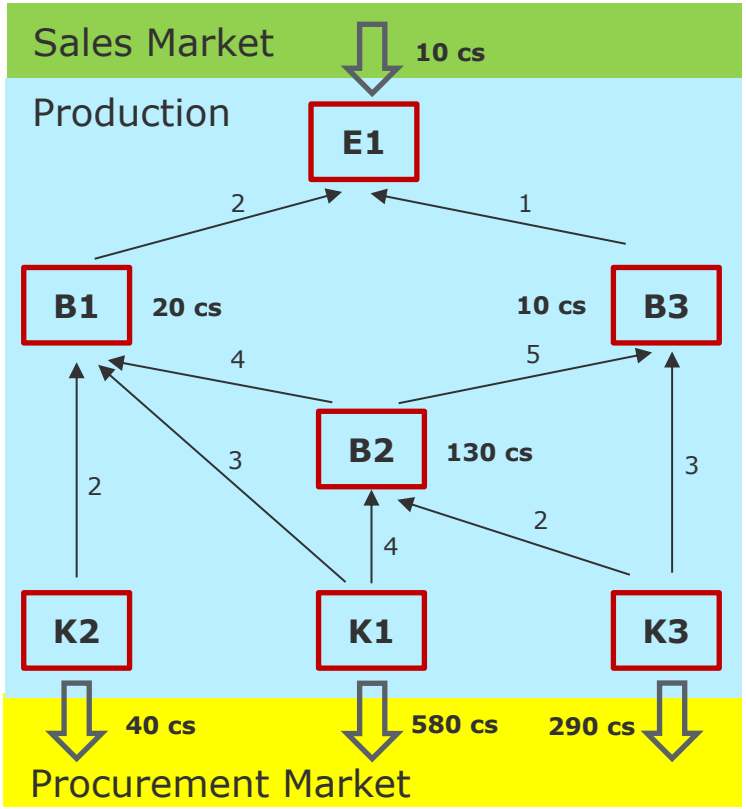
Calculation of forecast values

- Starts with sales demand
- Uses coefficients from overview type of bill of material to calculate demands for production und procurement

Assumptions

- No material on stock
- No time lag between sales, production and procurement
- No bottlenecks

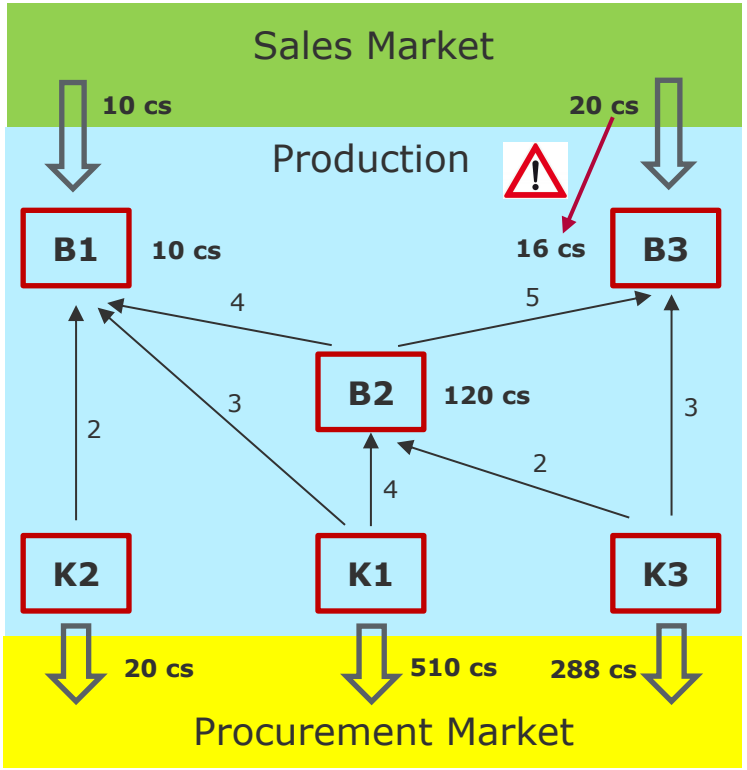
Produktion
Material Requirements Planning (MRP), based on sales program (2/4)



Calculation of forecast values

- Now with material on stock
  - Like in slide (1/4) plus
  - Subtract material on stock
    Gross calculation → net calculation
- Now with time lag function
  - Shift volume according to lead time
  - Period related forecast
- 1 bottleneck
  - Without alternative assignments:
    - Assign products to bootleneck resource
    - Calculate volume proportionally backwards
  - With alternative assignments: see slide (3/4)
- Several bottlenecks: see slide (4/4)

Produktion
Material Requirements Planning (MRP), based on sales program (3/4)



Calculation of forecast values

- 1 Bottleneck
  - Now with alternative assignments:
    - Optimal assignment of bottleneck resource according to target measure (eg. CM per time unit)
    - Sales volume, procurement volume

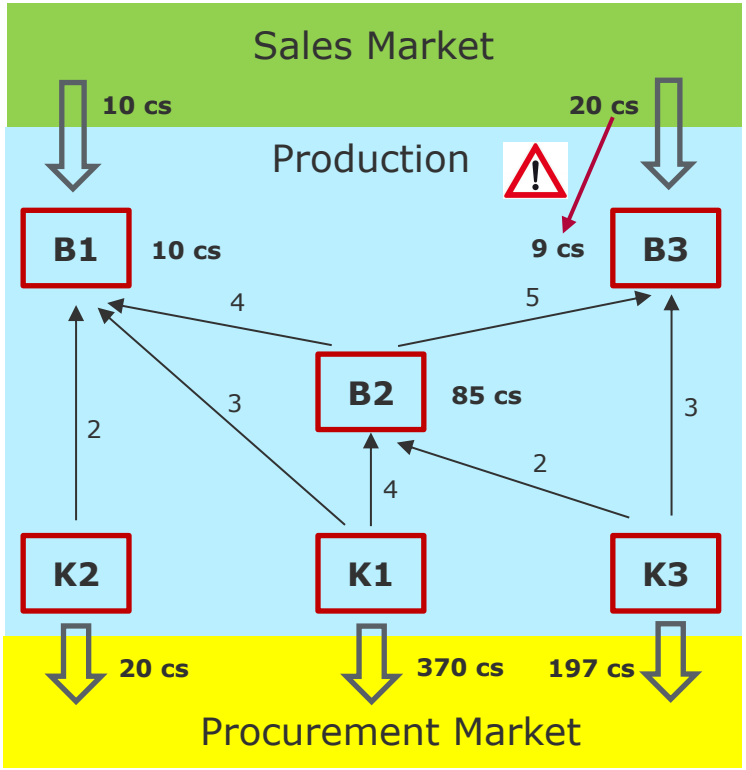
Product	Production Demnad B2 for …	Bottleneck usage B2 for …	CM/cs	CM/time unit of bottleneck B2 for …	Assignment B2 for …	Production B2 for …
B1	4 cs	1 h/cs	10 €/cs	10 € / 4h = 2,5 €/h	40 h	40 cs
B3	5 cs	1 h/cs	10 €/cs	10 € / 5h = 2,0 €/h	80 h	80 cs
B2					120 h	120 cs

CM: Contribution Margin

Bottleneck

- Several bottlenecks: see slide (4/4)

Production
Material Requirements Planning (MRP), based on sales program (4/4)



Calculation of forecast values

- Now with several bottlenecks and with alternative assignments:
  - Design and solve Simplex-Tableau
  - Calculate sales and procurement volume

P_{max} = 10 €/cs * X_{B1} + 10 €/cs* X_{B3} – 4.000 €

M1	4 * X_{B1} +	5 * X_{B3}	< 120 h
M2	8 * X_{B1} +	13 * X_{B3}	< 200 h
A1	1 * X_{B1} +	0 * X_{B3}	< 10 cs
A2	0 * X_{B1} +	1 * X_{B3}	< 20 cs

P: Profit Fix Costs: 4.000 €

X_{B1} = 10 cs X_{B3} = 9 cs P = -3.810 €

unused: M1 35 h M2 0 h A1 0 Stk A2 11 Stk

Simplex Tableau https://www.matopt.de/werkzeuge/lineare-optimierung/simplexalgorithmus.html

Production
Material Requirements Planning (MRP) – Plan Production Orders

Plan Production Order

Header

Items

- Item type *Material*
- Item type *AVO* (*Workprocess, Activity*)

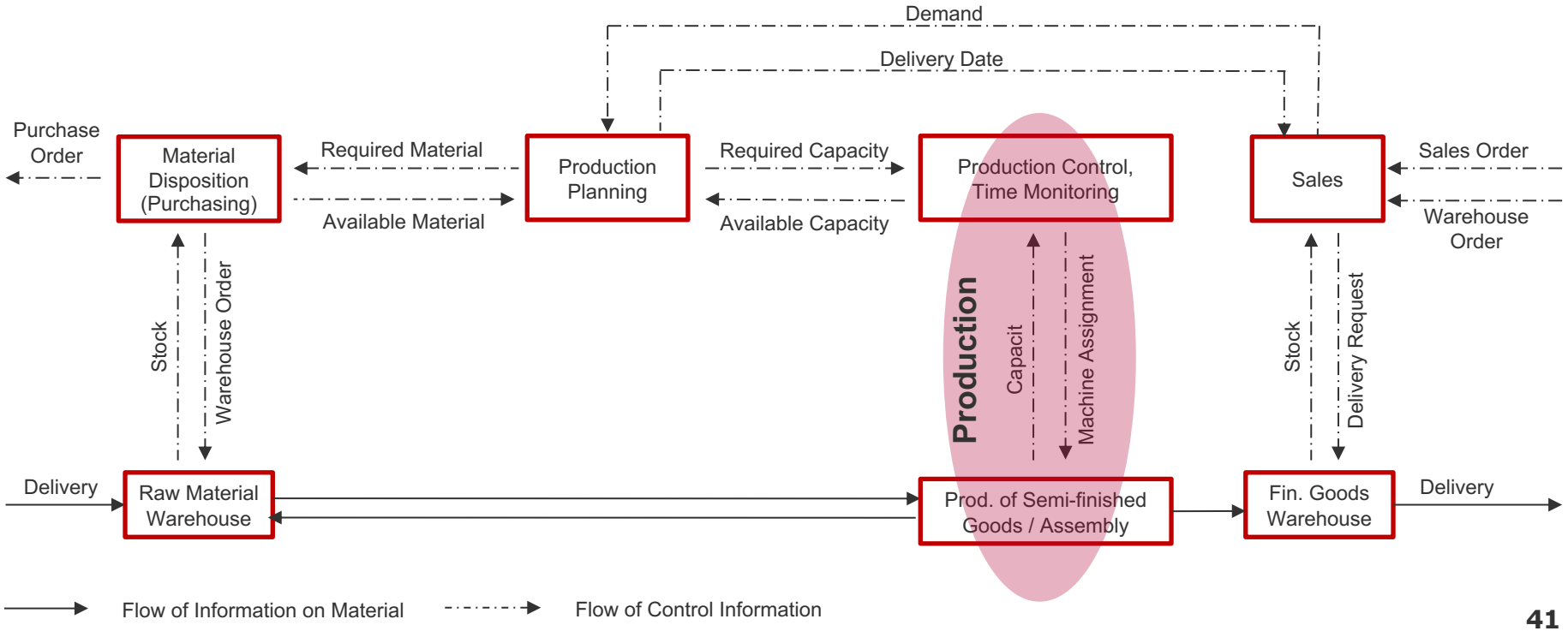
Plan Production Order #
Calendar Period Material Quantity

Item #	Type	Material	Quantity	AVO	Machine	Start Time	Duration

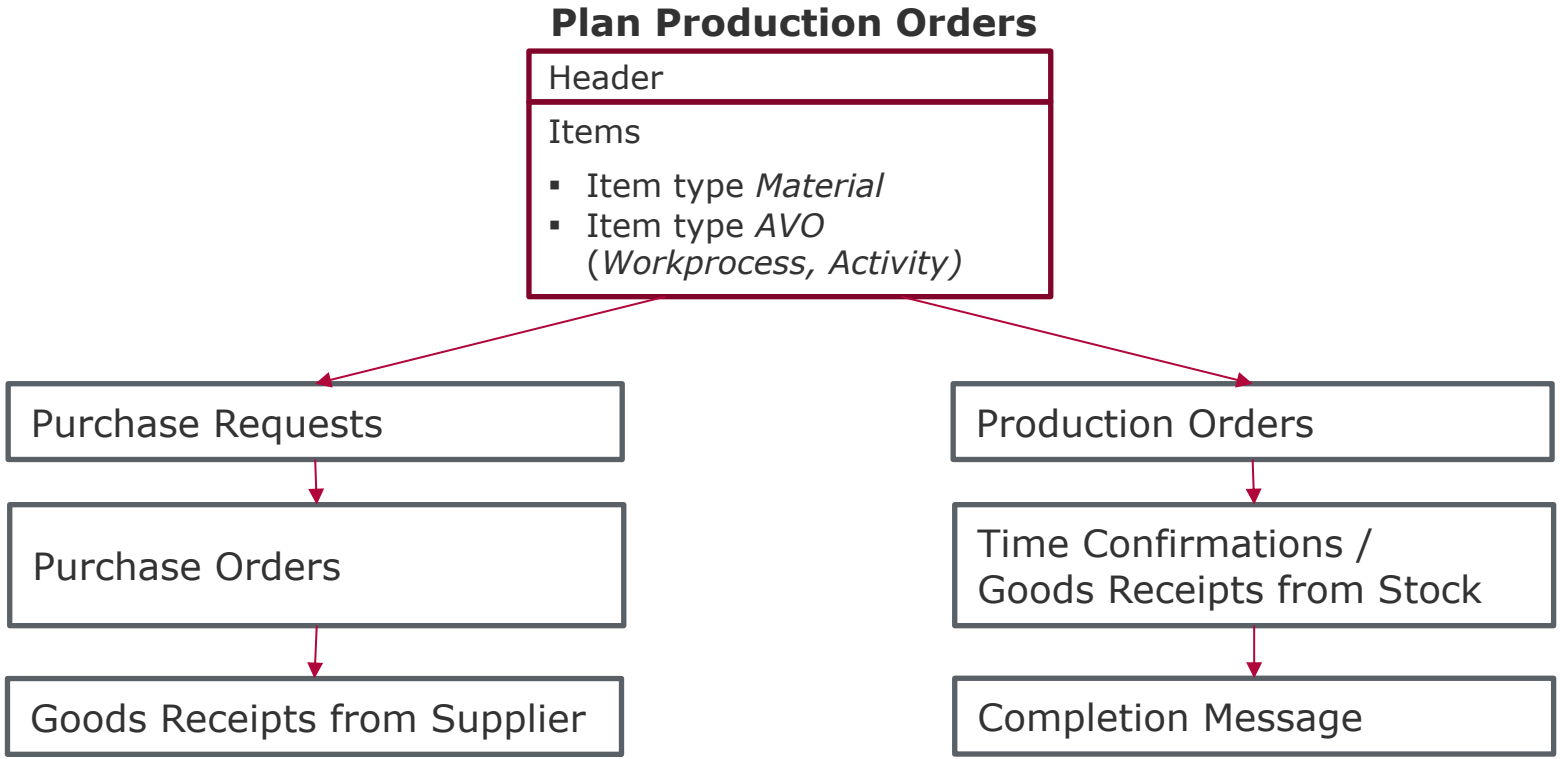
In a MRP run an optimized plan production program is determined and stored as plan production orders. Based on primary demand (sales demand and independent demand), expected availability of inventory (inventory on hand, open reservations, expected receipts), procurement requirements are calculated. Dependent on the procurement method these are purchase requirements or production requirements.

- Based on the production requirements and the applicable bills of materials (‘BOM‘), requirements for the BOM components are calculated, recursively through all production levels.
- Likewise, based on routings requirements for machine time and other ressources production work are calculated and allocated to the production work centers.
- Based on production requirements, routings and machine capacity an optimized production program is determined.
- The production program is recorded as plan production orders for the required materials and calendar-related times on machines.

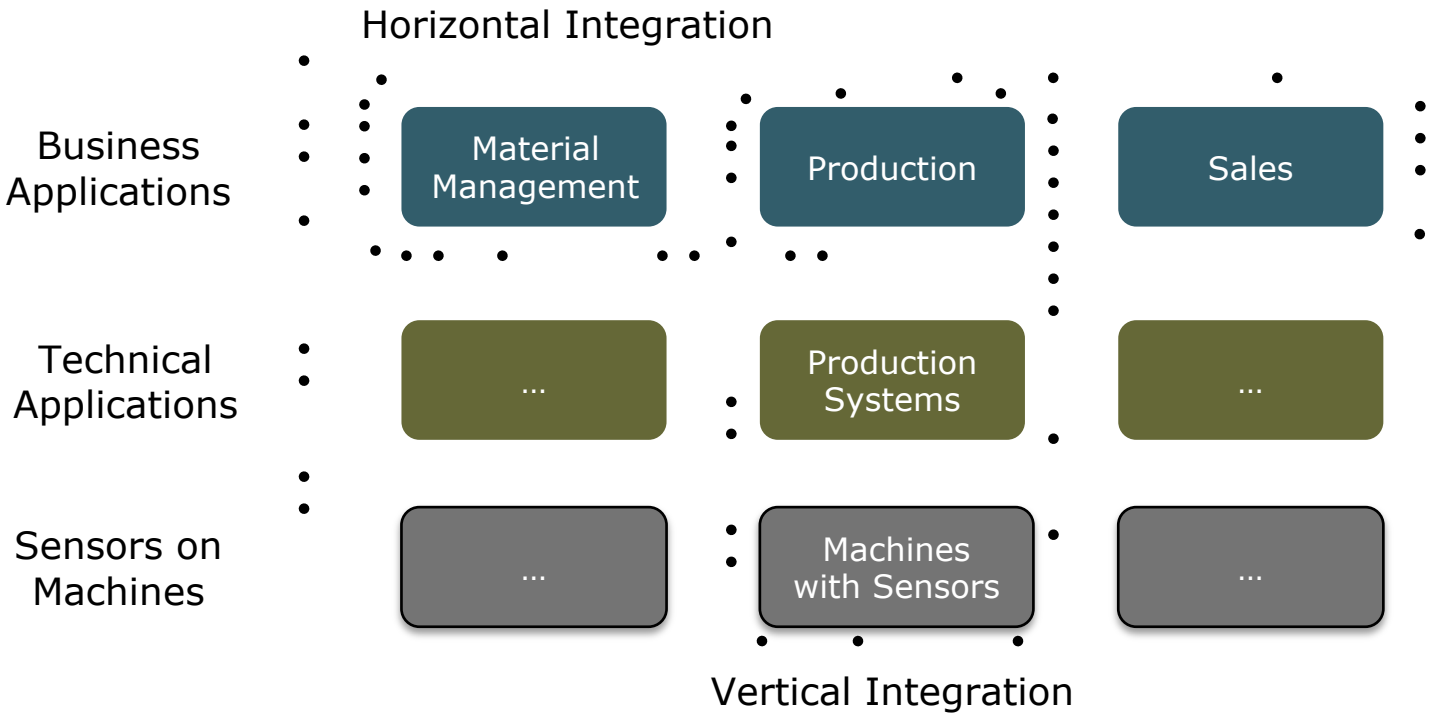
Flow of Goods and Values
Inside Production



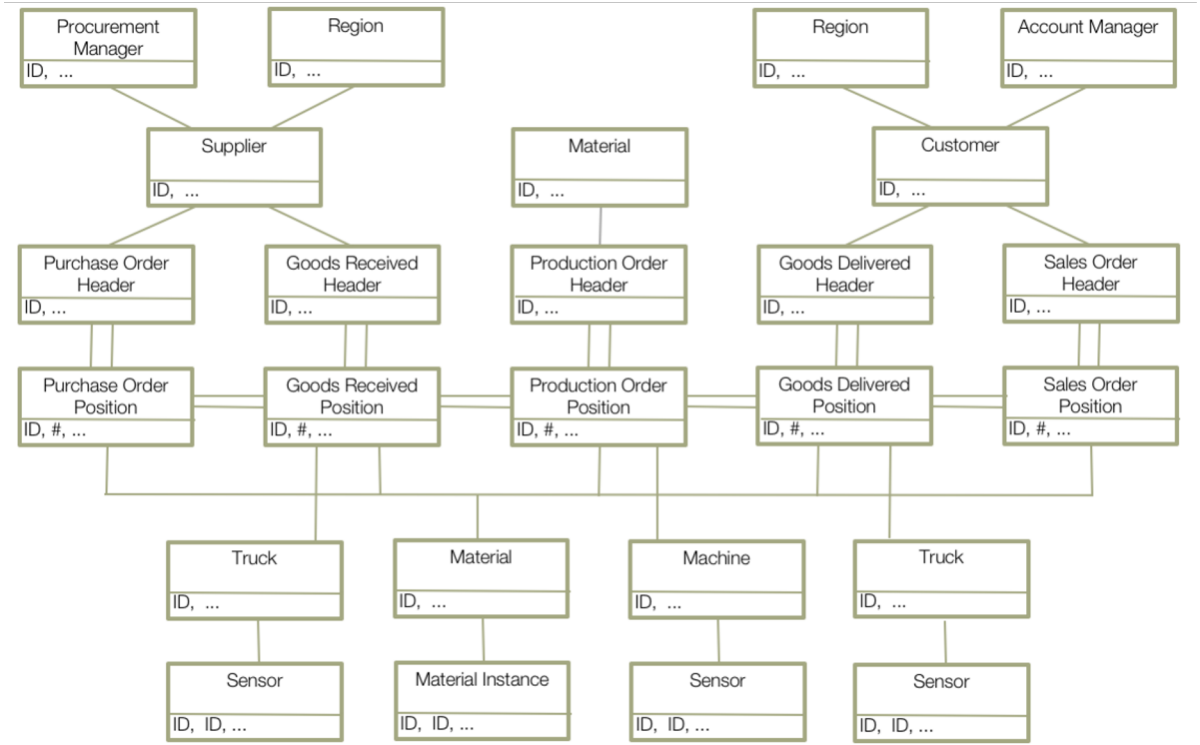
Production
Production process



Production
Systems



Production
Systems, Datamodel



Business Applications

Technical Systems

Sensors on machines

Production
Systems, Datamodel, Flow of Data

Saw		
Time	Noise	Temperature
…	…	…
8:09.05	90,2	30,02
8:09.06	90,4	
8:09.07	90,6	30,05
8:09.08	90,8	
8:09.09	90,9	30,04
8:09.10	91,2	
8:09.11	91,3	30,04
8:09.12	91,1	
…	…	…

Production Order	1234	Product	Cylinder
Plant	North	Planned	15 PC
Date	12.01.2022	Actual	15 PC

Material / Activity	Plan Quantity	Actual Quantity	Start	End
Steel Bar	1 PC	1PC		
Bolts	60 PC	60 PC		
…				
Saw	5 min	5 min	8:09	8:14
NC Machine	12 min	13 min	8:20	8:33
Automatic Assembly	3 min	4 min	8:50	8:54

Financial Document	9876
Company	Pumpen GmbH
Posting Date	12.01.2022

Pos #	D/C	G/L Account	Production Order	Cost Center	Amount
001	D	Machine hour	1234		100 €
002	C	Machine hour		ABC	100 €

* MES: Manufacturing Execution System

Appendix

Werner Sinzig

June 2022

Produktion
Planauftrag - vereinfacht

Header

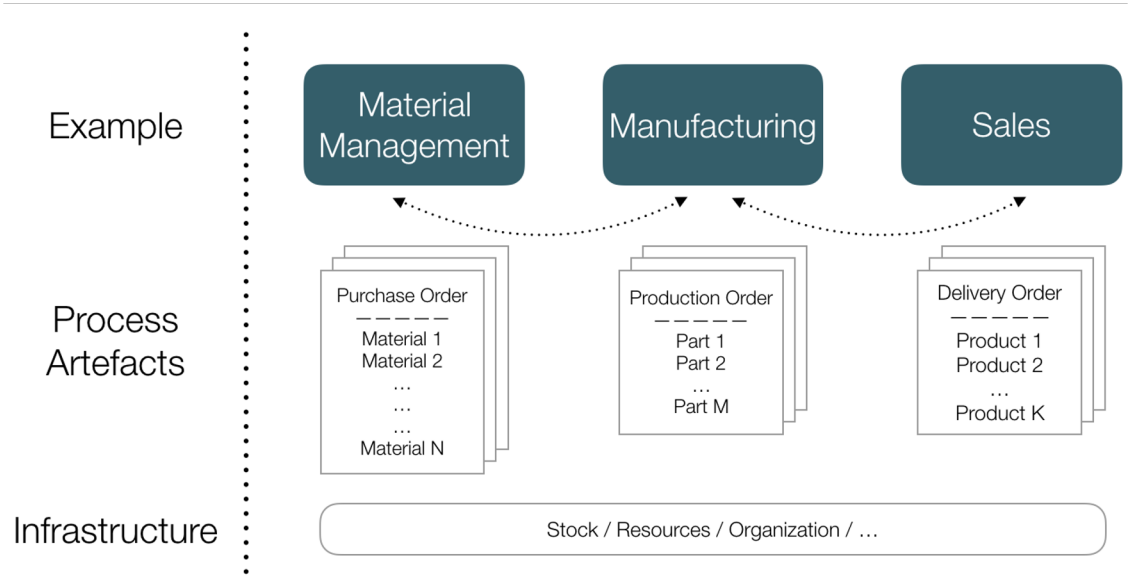
Positions

- Position type *Material*
- Position type AVO (*Workprocess, Activity)*

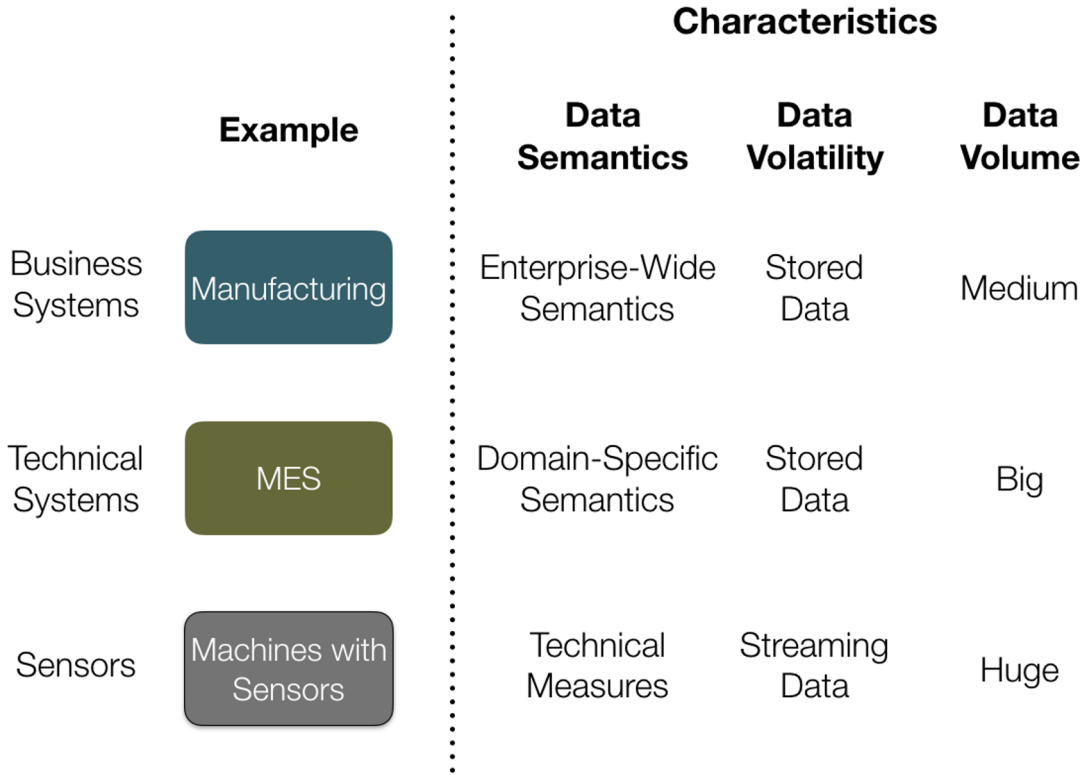
Plan Production Order #
Calendar Period Material Quantity

Item #	Type	Material	Quantity	AVO	Machine	Start Time	Duration

Horizontal Integration in Detail



Vertical Integration in Detail



IT Systeme im Unternehmen
Typen