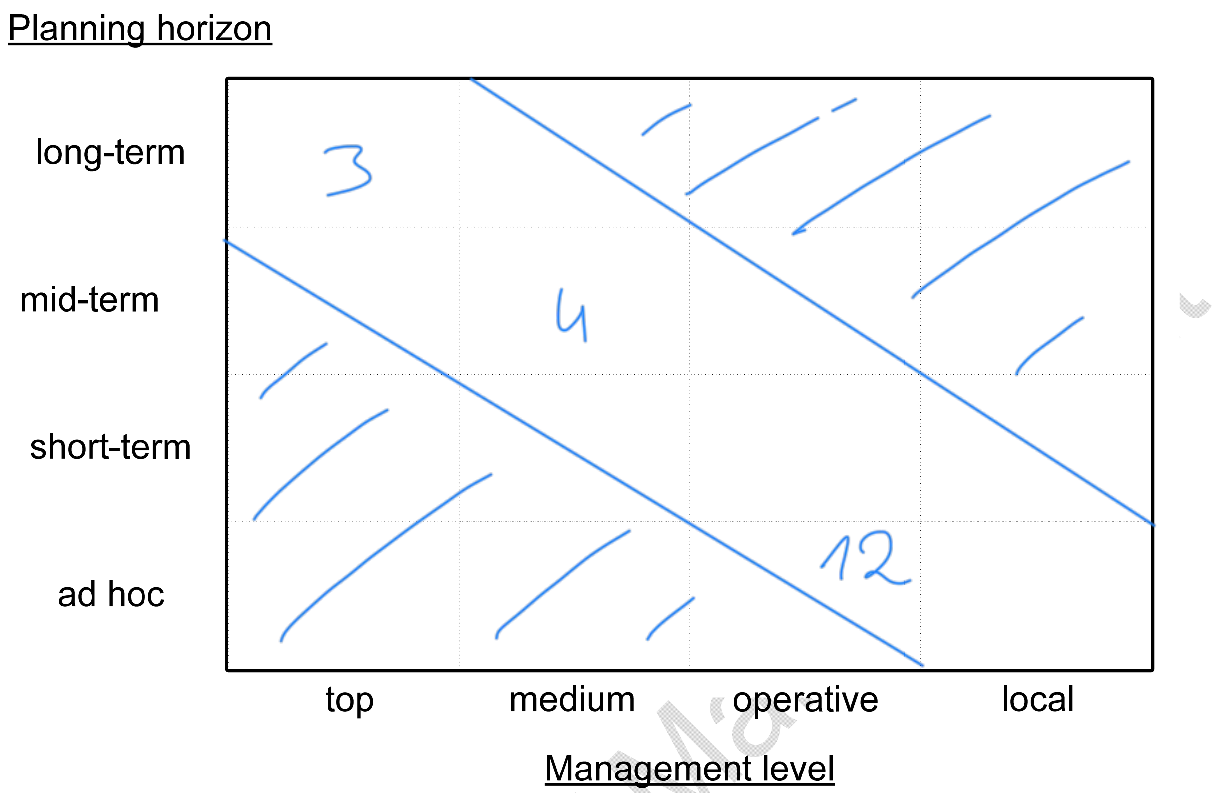
1. Introduction

- **Examples of decision making related to industrial production systems**



Decision making examples in production and operations management

(1) Change to a new automated production technology with the aim of gaining a competitive advantage;

(2) Setting up a new distribution center;

(3) Introduction of a new computer-based production planning and control system;

(4) Increase of the production capacity through investment in additional production equipment;

(5) Assignment of products to production sites within a logistics network;

(6) Establishment of a contract with a supplier for the introduction of a "just-in-time" supply mode;

(7) Determination of the prospective production quantities for the next 12 months;

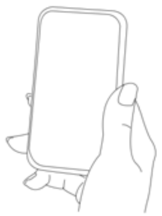
(8) Ordering of raw material;

(9) Acceptance of a new customer order;

(10) Exchange of information on stocks and capacity utilization within the supply chain;

(11) Assigning a production order to a specific work center;

(12) Rescheduling of the order sequence and timing on a machine after acceptance of a new major production order.

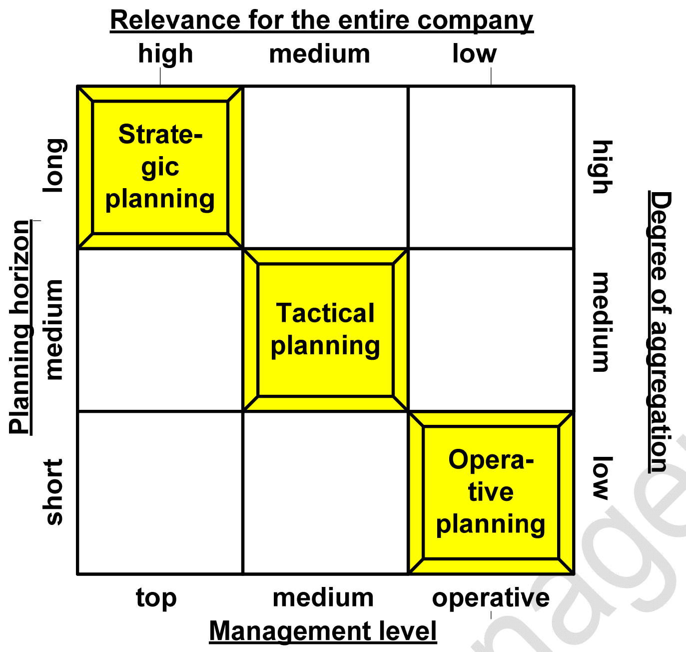


(1) Decision (3):
   a. has a mid-term horizon and is made by operative management
   b. has a mid-term horizon and is made by middle management
   c. has a long-term horizon and is made by middle management
   d. has a long-term horizon and is made by top management

(2) Decision (4):
   a. has a long-term horizon and is made by operative management
   b. has a mid-term horizon and is made by middle management
   c. has a long-term horizon and is made by local management
   d. has a long-term horizon and is made by top management

(3) Decision (12):
   a. has a short-term horizon and is made by operative management
   b. is made ad-hoc by operative management
   c. has a short-term horizon and is made by local management
   d. is made ad-hoc by local management

- **Planning levels**



Which planning levels are characterized by the following definitions?

1. *Determination of the entire company's long-term development (Establishment of framework conditions under which the company is enabled to develop successfully in the long-term)*

Examples:

a) Introduction of a new technology
b)
c)

2. *Design of the infrastructure of the production system*

Examples:

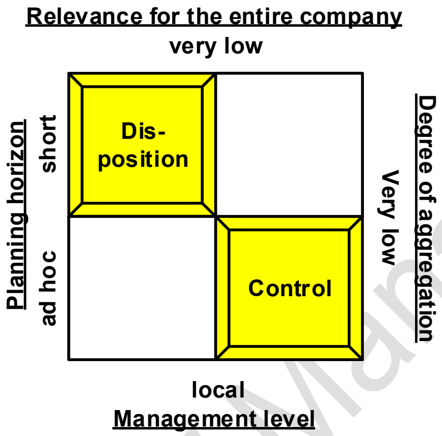
a) Scaling the production capacity
b)
c)

3. *Development of programs for the efficient use of the available resources*

Examples:

a) Development of the master production schedule
b)
c)

- **Execution levels**



Which execution levels are characterized by the following definitions?

4. *Implementing the operative production schedules*

Examples:

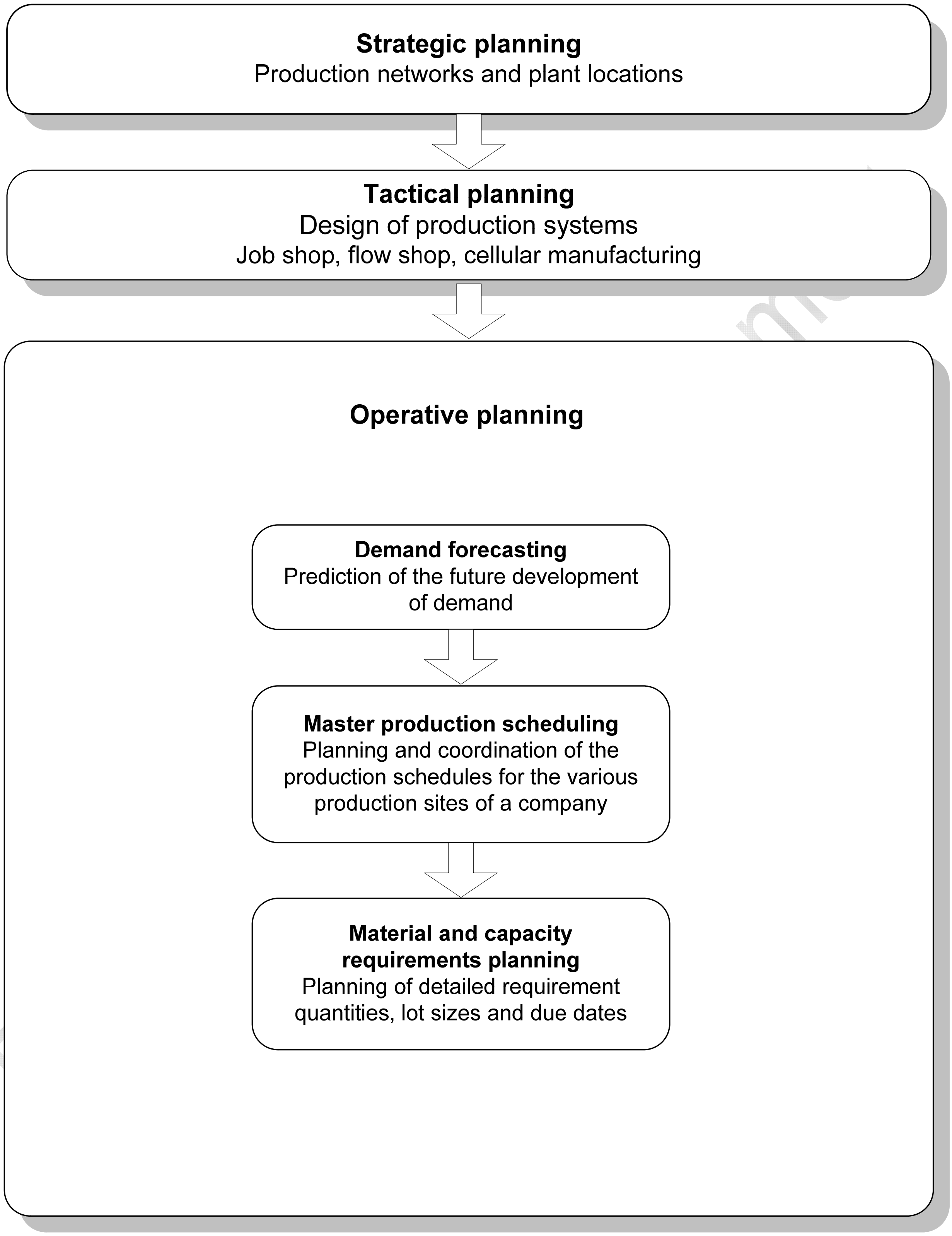
a) Order allocation
b)
c)

5. *Taking concrete control measures for the realization of the production targets*

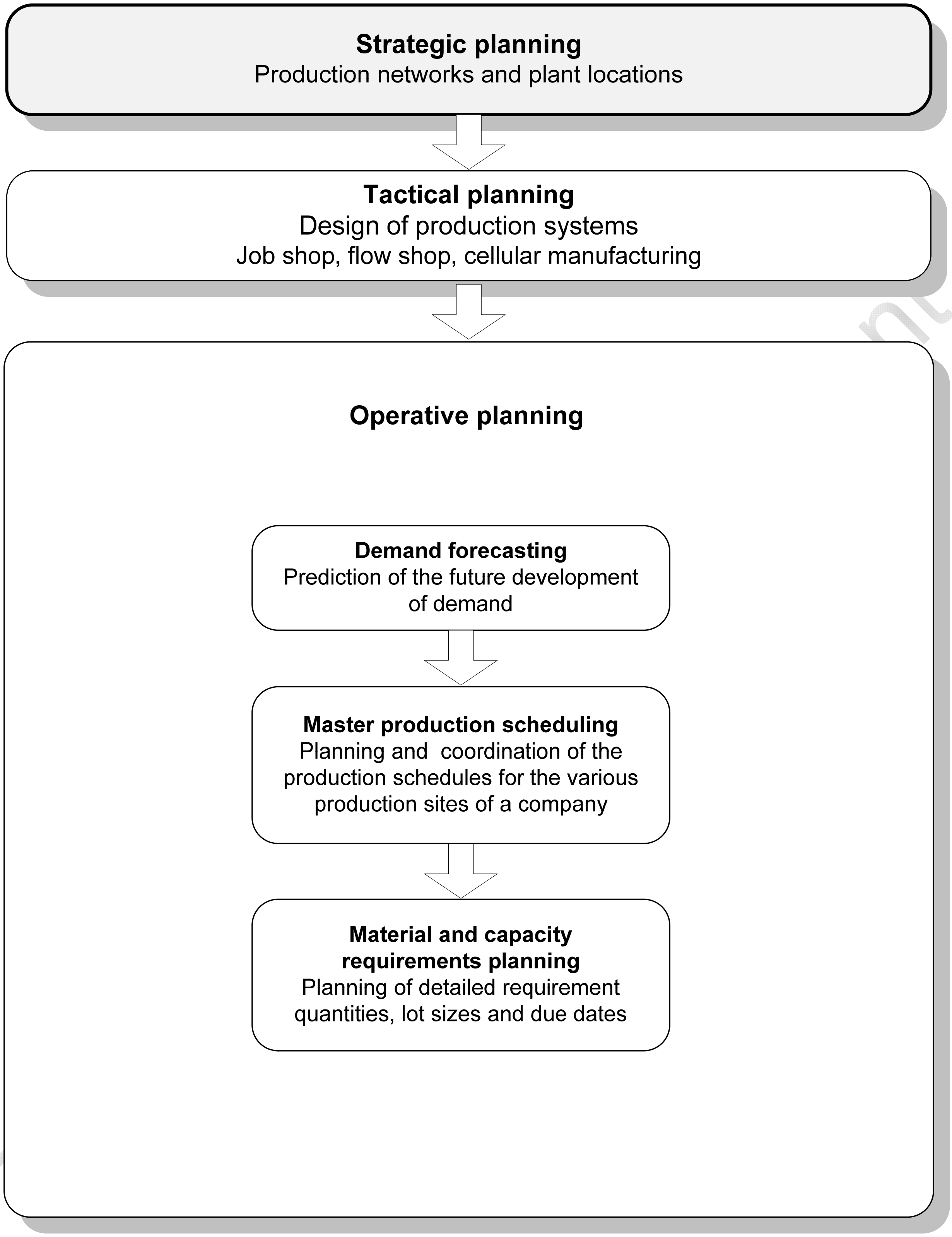
Examples:

a) Declaration of a rush order
b)
c)

Structure of the teaching module Production and Supply Chain Management:



2. Production networks and plant locations

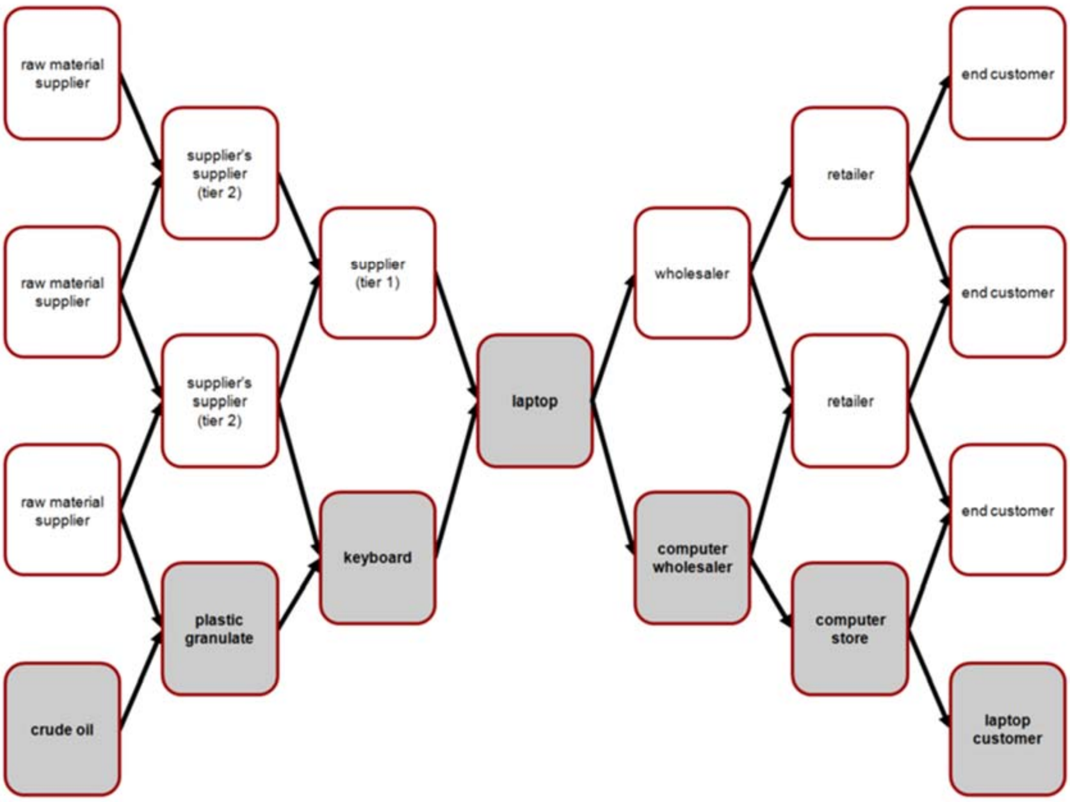

Strategic planning
Production networks and plant locations
Tactical planning
Design of production systems
Job shop, flow shop, cellular manufacturing
Operative planning
Demand forecasting
Prediction of the future development of demand
Master production scheduling
Planning and coordination of the production schedules for the various production sites of a company
Material and capacity requirements planning
Planning of detailed requirement quantities, lot sizes and due dates

2.1 Basic explanations and definitions

- **Supply chain management (SCM)**

  - ➢ **Geographically dispersed** suppliers, production facilities, distribution centers, customers
  - ➢ **Multiple stages** of supply, production and distribution
  - ➢ **Integration** of supply, production, distribution and sales activities
  - ➢ Distinction between **internal supply chains** (comprising entities within one company) and **external supply chains** (consisting of legally and organizationally independent parties)
  - ➢ **Exchange of information**, e.g. on capacity and demand within the supply chain
  - ➢ **Collaborative planning** mode supported through software systems

- **Supply and demand network**



http://en.wikipedia.org/wiki/File:Supply_and_demand_network_(en).png

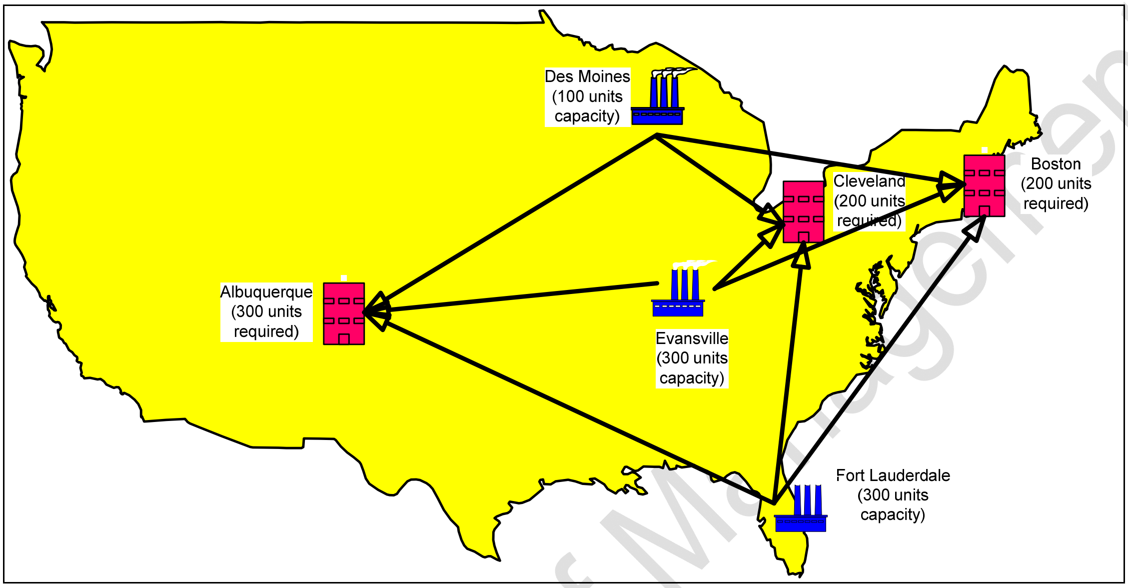
2. Classic transportation problem

⇒ Multiple production locations

⇒ Multiple customer regions

⇒ **Optimization problem**: Determination of the minimum cost transportation quantities

Example of a production-distribution system



From	To			Capacity
	Albu-querque	Boston	Cleveland	
Des Moines	5	4	3	100
Evansville	8	4	3	300
Fort Lauder-dale	9	7	5	300
Demand	300	200	200	700

➢ **Numerical solution**

- Various heuristics for determination of an initial solution (e.g. Vogel´s approximation method)
- Improvement methods (e.g. MODI method) to determine an optimal solution
- General optimization algorithms for linear programming

Vogel´s approximation method

Idea:

- Minimize the maximum additional costs for not selecting the optimum supplier or destination.
- Using additional costs incurred by selecting the second best (instead of the best) supplier or destination as a priority rule for the selection of transportation links.

Procedure:

(1) Determine cost differences for each row and column and identify the row/column with the maximum cost difference.

(2) For the selected row or column, identify the transportation link with minimum costs and set the transportation quantity equal to the minimum of available capacity and unfilled demand.

(3) Update cost differences, capacities and demand. In case the capacity of a plant is used up or the demand of a customer is completely satisfied, eliminate the corresponding row or column from the solution tableau.

(4) Repeat steps (1) to (3) until all demand is satisfied.

Exercise

Solve the transportation problem given in the table below using Vogel's approximation method.

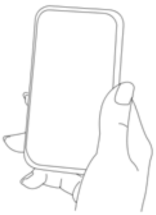
Production site	Customer regions 1	2	3	4	Capacity
1	7 (6)	7	6	4 (1)	7
2	9	5	3 (3)	3 (5)	8
3	7	2 (5)	4 (5)	7	10
Demand	6	5	8	6	

2 0 2←@

0 3 @↗ 1 1

6·7+1·4+3·3+5·3+5·2+5·4=100

- Transportation costs:



(1) The first iteration of the Vogel Approximation Method, determines the following transportation volume:
   a. 7 units between production site 1 and customer region 4.
   b. 8 units between production site 2 and customer region 3.
   c. 6 units between production site 2 and customer region 4.
   d. 5 units between production site 3 and customer region 2.
   e. 8 units between production site 3 and customer region 3.

(2) The maximum cost differences in the first four iterations of the Vogel approximation method are
   a. 3-3-3-6
   b. 3-3-3-3
   c. 3-2-2-1
   d. 3-4-3-4.

Transportation model

⇒ *Indices, index sets*

$i \in I$ plants

$j \in J$ customer zones

⇒ *Decision variables*

x_{ij} quantity transported from plant *i* to customer zone *j*

⇒ *Parameters*

K_i capacity of plant *i*

D_j demand of customer zone *j*

c_{ij} per unit costs for production at plant *i* and transportation from plant *i* to customer zone *j*

⇒ *Model formulation*

Minimize

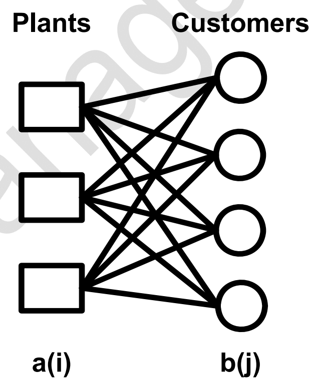
$$\sum_{i \in I} \sum_{j \in J} c_{ij} \cdot x_{ij}$$

subject to

$$\sum_{i \in I} x_{ij} \geq D_j \qquad j \in J$$

$$\sum_{j \in J} x_{ij} \leq K_i \qquad i \in I$$

$$x_{ij} \geq 0 \qquad i \in I, j \in J$$



➢ **Assumptions**

- Single period
- Single product
- Only transportation and plant specific production costs considered
- Linear cost structure
- All plant - customer zone assignments feasible
- Unlimited transportation capacities

➢ **Extension: Assignment of Distribution Centers (DCs) to plants**

- set the demand of a DC equal to 1
- calculate cost figures for allocating total demand of a DC to a specific plant
- determine unique assignment by use of the transportation model

2.2 Selection of a single manufacturing site

- **Reasons for opening new locations**
  - Increasing capacity
  - Modernization
  - Entering new markets
  - Growth of free trade zones
  - Lower labour costs
  - Strategic issues
  - Benefitting from exchange rate trends

- **Relevant factors**
  - quantitative (e.g. distribution costs)
  - qualitative

2.2.1 Evaluation of production and distribution costs for alternative plant configurations

Customer region	Transportation costs per unit				Demand
	Existing locations		Potential new locations		
	St. Louis	Boston	Denver	Dallas	
New Orleans	5	8	6	4	20.000
San Francisco	6	10	3	9	20.000
Atlanta	8	7	10	6	26.000
Baltimore	9	6	11	10	24.000
Production capacity	35.000	30.000	25.000	25.000	
Production costs per unit	15	18	16	17	

Only one of the two potential new locations (Denver or Dallas) has to be added to the existing ones. How are total production and distribution costs affected by the two feasible plant configurations?

Customer zone	Location						demand
	St. Louis		Boston		Denver		
New Orleans							20.000
San Francisco							20.000
Atlanta							26.000
Baltimore							24.000
production capacity	35.000		30.000		25.000		90.000

- **Total distribution costs**

Customer zone	Location						demand
	St. Louis		Boston		Dallas		
New Orleans							20.000
San Francisco							20.000
Atlanta							26.000
Baltimore							24.000
production capacity	35.000		30.000		25.000		90.000

2.2.2 Capacitated production plant location model

Based on the classic transportation model, hence also the following assumptions apply:

- Single period
- Single product
- Only transportation and plant specific production costs considered
- Linear cost structure
- All plant - customer zone assignments feasible
- Unlimited transportation capacities

Additionally, the following assumptions apply

- Costs for operating facilities and costs for producing and shipping goods from plants to customer zones given
- Potential locations and potential capacities of all facilities given

⇒ *Indices, index sets*

$i \in I$ plants

$j \in J$ customer zones

⇒ *Decision variables*

y_i = 1, if plant *i* is open; 0, otherwise

x_{ij} = quantity shipped from plant *i* to customer zone *j* per year

⇒ *Parameters*

D_j demand in customer zone *j*

K_i potential annual capacity of plant *i*

f_i costs for set-up and operation of plant *i*

c_{ij} costs of producing and shipping one unit from plant *i* to customer zone *j*

⇒ *Model formulation*

Minimize $\sum_{i \in I} f_i \cdot y_i + \sum_{i \in I} \sum_{j \in J} c_{ij} \cdot x_{ij}$

subject to

$\sum_{i \in I} x_{ij} = D_j \qquad j \in J$

$\sum_{j \in J} x_{ij} \leq K_i \cdot y_i \qquad i \in I$

$x_{ij} \geq 0 \qquad i \in I, j \in J$

$y_i \in \{0,1\} \qquad i \in I$

Example

Develop the capacitated plant location model for the example shown in section 2.2.1.

Minimize

subject to

Demand

Capacity

Number of plants

Variable domains