Factory Planning

Ng Phuc Phuc

L1,

1, Introduction:

- Definition:
  - Location structure: arrangement of locations in regional area
  - Plant structure: _____ buildings on factory site
  - Layout: _____ areas within building
  - Workstation design: _____ objects at workstation

- Factory planning is a project, but differentiate in 4 domains

Object
- 3D cube: hierarchical level / basic functions / production elements
  - categories
- From customer perspective: 6 types: low-cost, high tech, responsive (time), variant-flexible (diversity), customized, breathing (seasonal fluctuation) / factory
- 5 categories of influence: world economy, politics, environment, society, technology

Cause & Target
- 5 basic cases:
  - New planning (Greenfield planning): New construction
  - Re-planning (Brownfield planning):
    - Reconfiguration
    - Expansion
    - Deconstruction
    - Revitalization
- Reasons: Flexibility vs Efficiency, Availability vs Utilization, Redundancy vs Complementarity, Scope vs Scale

Subject: 3 the planner, planning team, client

Approach

preparation
structure planning
detailed
implementation

⊛ Aachen approach of factory planning:

- Temporal structured FP approaches: 5 phases
  neglect the dynamic ~~case~~ cause - effect relationships
  ⇒ develop the Aachen FP procedure new

- Evaluation model: { planning efficiency / planning effectiveness } ⇒ Return of Planning

$$ROP = \frac{PAV}{PC}$$

PAV = Planning added value
PC = Planning cost

- Modular approach ⇒ { visualization / dependancy between those modules }

- Planning modules:

required info from customer

input from previous moduls → modul → output

Tools

2) Project management:

+) Theoretical:

- 6 Characteristics:
  - level of innovation & risk
  - team work
  - clearly defined objective
  - interdisciplinary
  - limited time & uniqueness
  - not feasible through existing organization

- 6 framework conditions: time schedule, cost
  scope, quality
  resources, risks

- 3 main phase: Planning, Execution, Control

- Agile project management: evolved in software development.

+) Practice:

- 10 steps in framework for preparation

- Analysis of project environment: Stakeholder / Project | analysis

⇒ Extend to Project Context Analysis

- The composition of project team: structural, situational, group dynamic, personal | aspects

- Charta

- Gant-chart: Milestones & Deliverables

- Reflection & review

⊗ Cost func: $PC = E^{a} G + Z$

Utility func: $N = \sum_{t} \frac{N_t}{(1+z)^{tt}}$

Planning Benefit: $PB = N \frac{PC}{PC + \Sigma X_i + \Sigma I_t}$

⇒ Planning added value: $PAV = PB - PC$

Questions: - Define location structure, plant structure
layout & work-station design

- How can a project be differentiated with a project?
- Basic factory planning cases?
- Which types of factory from a customer point of view exist in factory planning?
- Describe the evaluation model of FP and the concept of ROP (Return on Planning)
- How can the Aachen FP procedure be characterized?
- What are the characteristics of a planning module?

- What are typical characteristics of a project?
- Which different phases does a project go through?
- What internal & external influences is the project team exposed to?
- Why is it important to consider the social environment of a project?
- What is the name of the method used to analysed the social environment in a structured manner?
- How should one deal with critics & opponents in a project?

FP

Definition of Goals & Product / Process Analysis

L2)

2.1, Definition of Goals

- 6 steps: Definition of Project goals, prioritisation & quantification
  Key figures + current/target value
  task assignment

  project budget, identification of project risks
  ⇒ development of prevention strategies FMEA (failure mode & effect analysis)

  Project structure plan (PSP), Time Schedule
  Planning modules, tasks & capabilities, work packages
  milestones, deliverables chronological ordered

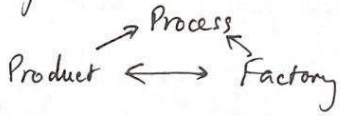
- Change project goals, during execution, causes high effort & costs

2.2, Analysis of production & processes

- Traditional FP ⟹ Intergrated FP

Product → Process → Factory

process only based on product
factory structure based on process

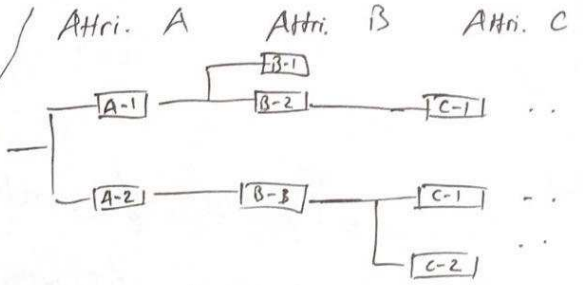


adapted to follow-up products
correlated to the life cycles of factory

7

From product functions ⇒ develop technical product structure / description

Use Attribute Tree:



Product attributes from customer perspec. ⇒ external variance

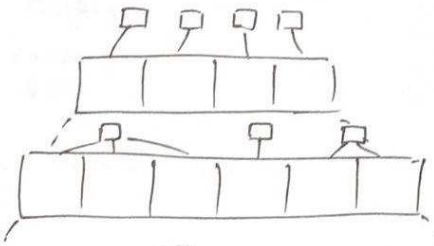
1, Understanding product functions & analysing product structure

2a, Capturing product variety

2b, Determining the sequence of processes

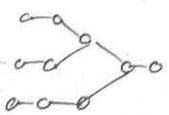
Internal complexity

Variant Tree



Flow chart  for process analysis of new products depict production process chain

or

Process Sequence Graph 

3, Creating product families

Linked in product family matrix

Group variants with similar processing steps

Reduce no. products considered & ↓ complexity

4, Analysing historical data

ABC & XYZ analysis: sales & predictability

5, Determining future product & production program

Sales forecast

6, Defining reference products

Focus on products with high value/quantity well predicted, reduce complexity

AX

FP

Location & Plant Structure Planning

last for more than a generation (10 - 30 years)

L3,

1) Location Planning = site planning

⊛ 2 Phases: Global Footprint Design ⟷ Location Selection

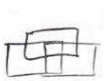
+) Global Footprint Design:

Corporate Initiative
- 3 different motivations: { new foundation / relocation / decentralization

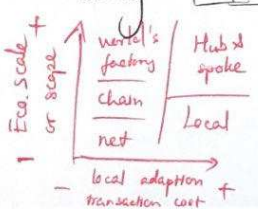
Scope of value creation
- Describe value creation in 3 dimensions
  - depth: less risk with lower level of depth, ex: only assembly
  - width: variety of products
  - Intensity: production volume
- Make or Buy decisions define the future depth

Strategic position the location in the corporate network
- Ways to allocate value creation to sites:

Decision Variables: { By volume / By products / By process

Alternatives: { Complementary  vs Redundancy 

- 5 network structures from relation between product - location perspective



Network concept

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+) Location Selection:

Location factors — 3 steps:
- Global: General, Economy, Labour market environment
- Regional:
- Local: Traffic, Energy, Real estate, water

- Set up profile requirements — K.O. requirement vs minimum requirement
- Compare
- monetary assessment — Preselection of location alternatives ⇒ Qualitative location assessment ⇒ Monetary location assessment
- Decision

2) Plant Structure Planning: arrangement of buildings on site

- Consider long-term factor
- 3 steps:
  - functional zones: list down all zones
  - functional & logistic axes:
  - expansion steps

1) Functional zones — Functional zones: production, warehouse, shipping, administration, parking..

2) Functional & logistic axes — 5 popular plant structures, each with pros & cons

	pros	cons
T-structure	easy expansion, 2dim optimal flow,	low land use efficiency
Line	easy expansion simple direct supply	intense traffic on central axes expansion only 1 dimension
Block	short distance high land use eff.	poor info. flow
Central axis	ez expansion, .. high land use eff	no central info hub
U structure	ez expansion simple direct supply	intense traffic in middle expansion of central difficult

3) Expansion steps — Expansions:
- flexible buildings & standardisation
- oversizing (3 steps):
  - estimate future space required
  - consider restriction of existing buildings..
  - ⇒ concept for future plant structure

Questions:
- Which 2 phases are part of location planning?
- What are the 3 dimensions of value creation?
- According to which criteria can the distribution of value creation to various locations take place?
- Which are the 3 levels of location requirements?
- What are the basic types of a plant structure?
- Which steps take place in plant structure planning?

L2)
- Which methods are applied when conducting a risk assessme
- What is the purpose of project structure plan?
- What do we understand about project milestones?
- What does the attribute tree describe and what for the variant tree? Which important insights / finding can be gained?
- What is a product family & reference product?
  Describe the approach for determining a product family as well as the approach to reference product?

FP

Production Structure Planning & Capacity Planning

L4,

1, Production Structure Planning: to secure efficient processes in production

- Conventional factory arranged in units ⇒ Now An assembly with flow orientation
- Increasingly complex tasks ⇒ thus centralized management & control is difficult to achieve

3 steps: ① Production Segmentation – Organisational Structure of Production

+, Divide by
- Market / Objective Orient.: fast sellers vs exotic birds
- Product Orient.: coordination effort, vertical intergration
- Multiple steps in logistic chain: mount, paint..
- Transfering indirect func.: transport, maintenance, controlling, ..

⊗ Aim: a stringent concentration of all required activities

⊗ Difficulty: slightly redundant structures can occur

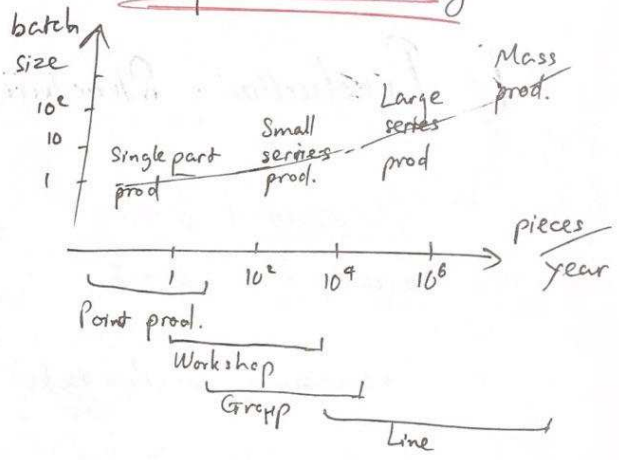
(2) Selection of Production Methods

- Definition of 4 Methods: classify based upon human, temporal, spatial

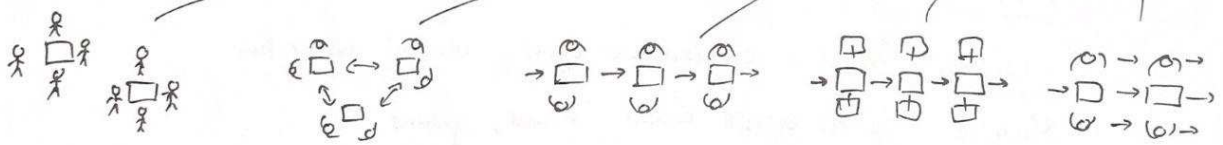
Spatial Structuring

Station \ Object/Product	fixed	movable
fixed	Group prod.	Line prod.
movable	Point prod.	Workshop prod.

Temporal Structuring



- Manufacturing: Workshop, Group, Line
- Assembly: Workstation, Group, Series, Line, Flow

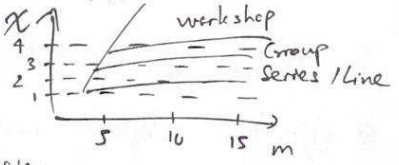


- Degree of cooperation: to choose production method

$$\chi = \frac{\sum k_i}{m}$$

$\rightarrow$ no. of workstation connected..

$\rightarrow$ no. of ——



(3) Process planning & Value Stream Design

- Classically: Planning Sequence: Product → Technology → Resources → Process

Now:

Start ⟹ Tech. Chain planning → Value Stream Design

+) Value Stream Design: to makes entire value stream visible
⇒ to improve design of prod. processes

- Simple images + graph
- Improve by: avoid material stocks, continuous flow, relayout..
- 4 Steps: Selection of product family ⇒ Designing of the actual state ⇒ Designing of the target state ⇒ Implementation

2) Capacity Planning

increase productivity of factory → max
dealing with fluctuating demands

- Internal + External factors (changes in products, variants, numbers ..)
(restructuring change in tech..)
- Challenges:
  - Inaccurate forecasts
  - Inaccurate data
  - Uncertainty
- To maximize possible perf. given .. in given time
- Objectives
  - Determine necessary resources
  - Whether what available is sufficient
  - Allocate stuff
- Max. availability ≥ Max. Utilisation
  - over capacity
  - higher resource costs
  - capacity short falls
  - supply shortage

⇒ core competency technology should be in the upper half, basic tech. close to lower limit line

3 steps methods:

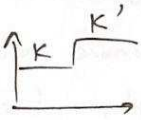
① Identify capacity needs ⇒ ② Determine deficit (compare need vs available) ⇒ ③ Action: technical ∨ Investment

- Standard times
- Machine profile
- Evaluate potential alternatives (quantitative qualitative eval..)
- Approaches to reduce cycle time & costs
- SMED (many tasks in parallel)

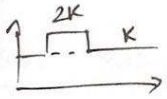
+/- Dealing with fluctuating demand: 3 capacitive approaches

Capacity flexibilisation	Redundant cap. utilisation	Cap. Harmonisation
- Meet actual capacity requirements	- Classification & segmentation of capacity to similar process	- Production controlling for synchronous utilisation of resources regarding capacity limits

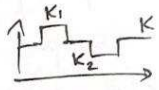
Approaches:

- Investments: 

case of good forecast
↓ cost
↓ flexib

- Additional shifts: 

short term change
↑ flex.
↓ cost night shi

- Overtime / short time working: 

short term change
↑ flex ↓ night shift cost

- External productions: 
bad forecast
↓ cost + know how + quality

Questions:
- Name different forms of production in manufacturing & assembly including pros & cons
- Name different possibilities of efficiency increasing
- Name differentes in spatial and temporal structuring
- What is value stream design?

- What are the challenges & goals in the context of the capacity planning?
- What is OEE?
- You want to reduce both processing time & costs of production? Where are effective arrangements & what measures to apply?

FP

Industrial Facility & Building Design

L5,

1) The factory building in planning process:

+) Structure of planning process:

Client ⇒ Architect ⇒ Contractor ⇒ Client

Target values Strategy Documents	→ Approvable planning basis Documentation	→ Build	→ Use.. Observe New plans..

In reality, phases are not clearly separated

+) Participants in the planning:

Client, factory planner, architect, project controlling, building contractor

HOAI (Honorarordnung für Architekten und Ingenieure)

+) Work load:

Prepatory planning	→ Ideal planning	⇒ Finer details	⇒ Detailed planning	⇒ Performance	⇒ Completion
3%	7%	11%	31%	45%	3%

+) Design task: Industrial Building

- Product change
- Market entrance variety
- & other possible scenarios

⇒ Different utilization cycles

⇒ flexibility is a requirement we need to adapt to the change of production goals

- Different sectors have different length of utilization cycle

average life span of a building > length of utilization cycle

- Life span of - building technology: 15..
  - primary structure: 30..

+) Influencing factor:

Internal	External
corporate image, client.. product, production..	technological change, climate demegraphic change

⇒ External factors are determined by a production site analysis

- Considerable criteria for site selection: purchasability, infrastructure constructability, environment, availability of work force, subsidies.

+) Site analysis:

- land use plan:
  - concept of utilization
  - border (inner, outer..)
- zoning ordinance: could be: with / without
  - coverage ration
  - utilization factor
  - distance space
  - building lines / street lines

Violations? ⇒ expensive delays even prohibition of construction

+) Site geometry impacts ⇒ typology, orientation, expandability

+) Internal factors:

Hard factors ≷ Soft factors

product & production
logistics
flexibility & variability

workplace quality
communication
corporate culture

2) The development of building concepts:

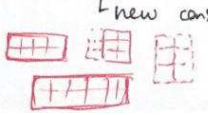
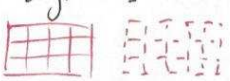
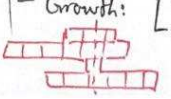
- System levels of industrial building:

Site → 1. Structure ⇒ 2. System → Components ⇒ Elements

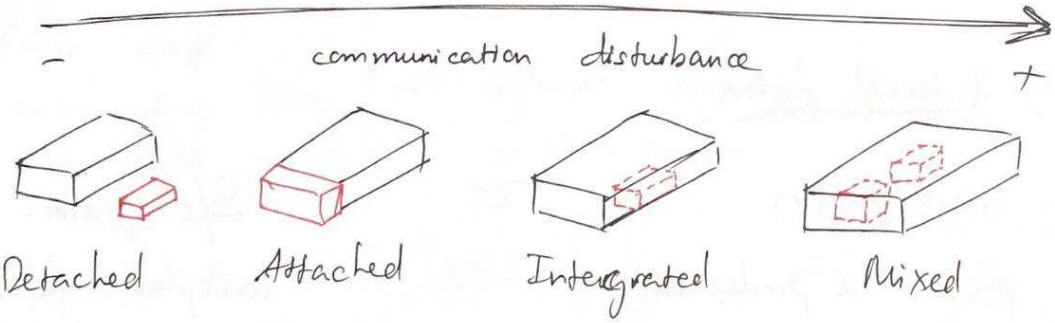
1. Structure: conception of space, pattern of use
2. System: Building tech
Components: Column, beam, bracing, supply & disposal
Elements: Steel, concrete..

+) Typology - Building Shape:

Campus / Court yard	Compact / Block Structure	Axis / Comb / linear structure	Amorphous Shape
Limited links	Short routes	- Increase orientation within site	- Easy to restructure
growth: [expansion / new construction]	growth: addition of segments	- Close relation: logistics & building	- Growth: expansion .. any place..
		- Growth: [expansion / mirroring]	


+) Disposition of office space:



+) System levels: 2. System

Bracing — ability to transform →
4 wall — 3 wall + cells — fixed column

Building control unit — space require flexibility → cost
centralized — decentralize

/ FP

Layout planning & workplace design

L6)

1) Layout Planning:

→ Definition: While: location planning ⇒ location structure: network of site in regional area

Plant structure planning ⇒ factory structure: arrangement of buildings on factory site

⊛ Layout Planning ⇒ { Building structure: arrangement of areas within a building
Area structure: arrangement of workplaces or machines within an area.

→ Challenge: ensure the best economical production under changing conditions (dynamic of quantity & shorter tech. lifecycles)

→ 6 quantitative & qualitative criteria must be considered

Value-stream oriented { Process focusing, Area efficiency } > < { Flexibility, Ability to change } Adaptability

Transparency (+) Communication (+)

The main criteria are contradictory ⇒ consideration is only possible to a limited extent.

The performance of the production system depends fundamentally on a suitable layout

2

↳ Development of the layout: 3 phases, 4 steps

Definition of target criteria → **Rough Layout** → **Detailed layout**

From:

Strategy (of company or products)
+
Product & processes
+
External influences

⇓

Pair-wise comparison

⇓

Chosen & prioritized criteria
(6–8 well-defined ones)

1) Ideal Layout

neglecting restrictions

- Many computer-supported algorithms, common goal to minimize transport effort, rarely used in practice
- Transport matrix

⇒ typical basic layouts

⇒ Layout Evaluation

2) Real Layout

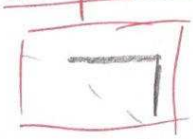
- From ideal layout, workshop with all stake-holder to discuss

Detailed planning of

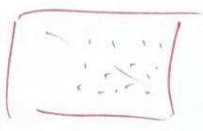
- Work places
- Material routes & logistic areas
- Technical building equipment

⇒ Construction planning
Cost calculation
..

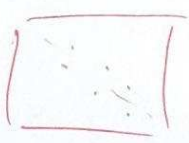
⊛ Transport matrix:



point Prod.



workshop Group prod.



line flow prod

2/ Work place design:

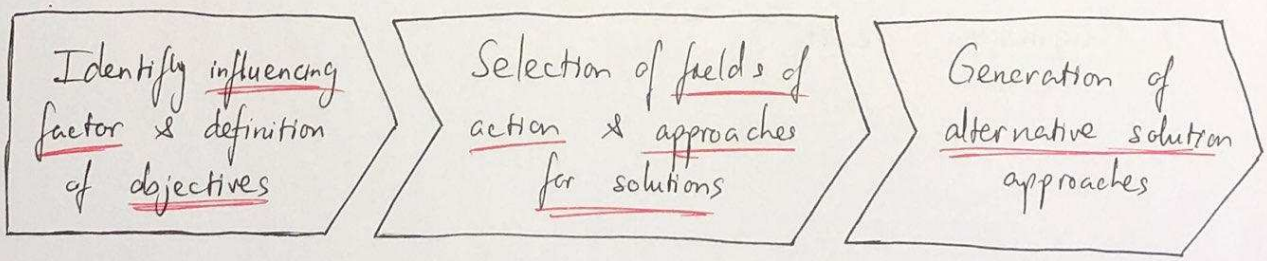
+/ Definition: Work place design ⇒ arrangement of objects at workplace

+/ 3 main objectives:
- productivity & quality
- long term efficiency
- safety & laws

+/ 4 fields of action:
- process optimization
- arrangement
- visualization
- standardization

+/ Age-related physiological shift: need to be considered

⊗ Procedure: 3 steps



- Quantity dynamics
- Variant diversity
- Product life cycle
- Legal requirements

- Space within reach
- Field of vision

} affect ⟹ optimal workplace design

- Cardboard engineering: as an intuitive validation

+) Workplace optimisation via 6S:

Seiri	Eliminate unnecessary parts
Seiton	Gain visible tidiness
Seisô	Create cleanliness in all areas
Seiketsu	Standards, to ensure organized states
Shitsuke	Live self-discipline
Shûkan	Reliable routine with all activities

+) Augmented reality:

Ex1: $PC = \dots$

$$N = \sum \frac{N_t}{(1+i)^t}$$

$$PB = N \cdot \frac{PC}{PC + X + I}$$

$$PAV = PB - PC$$

$$ROP = \frac{PAV}{PC}$$

$$T_k = z \left(\frac{t_r}{z_L} + t_e \right)$$

piece / batch / manufacturing

$$T_k^* = T_k \cdot \frac{1}{z_G \cdot k_n}$$

$$T_v = T_s \cdot z_s \cdot z_{de}$$

$$m = \frac{T_k^*}{T_v}$$

Ex3: $W =$ 

$$NS = |W_{min}| + 1$$

Absolute weigh: $AW = W + NS$

Relative w.: $RW_i = \frac{AW_i}{\sum AW_i}$

Normalised weigh: $NW = \text{Round}\left[1 + cf. \frac{AW}{\max(AW)}\right]$

$$C_0 = \sum C_i (1+i)^{-t}$$

- income = sale + depreciation + ... + ~~tax~~
- cash flow = sale + ~~de~~ + ... + tax

net income = sale + dep + ... + ... + tax

project status = prev. status + cash flow

interest = proj. status • debit interest