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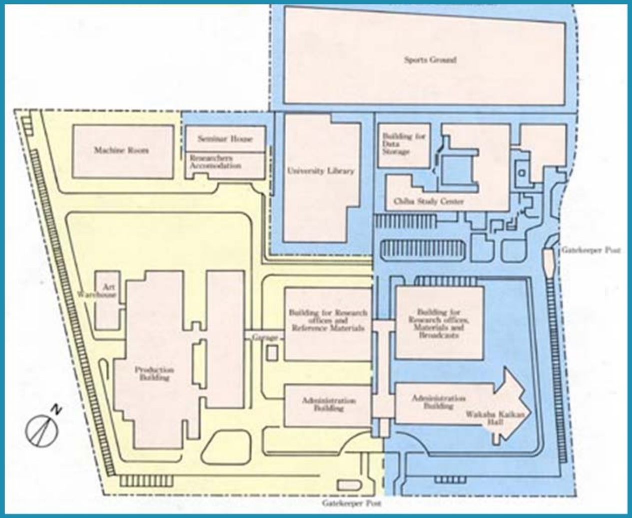
Layout



Agenda

What ? - Types -
Impact - Flows

Traditionele MP – CAL -
Developments

How ? - Impact

Wayfinding – Layout
& core business

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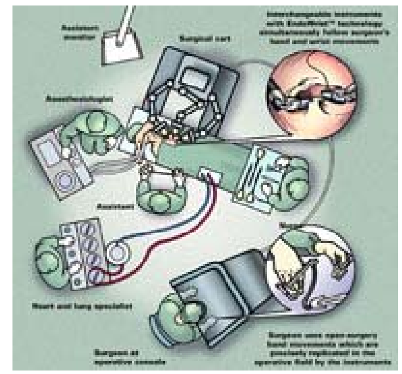
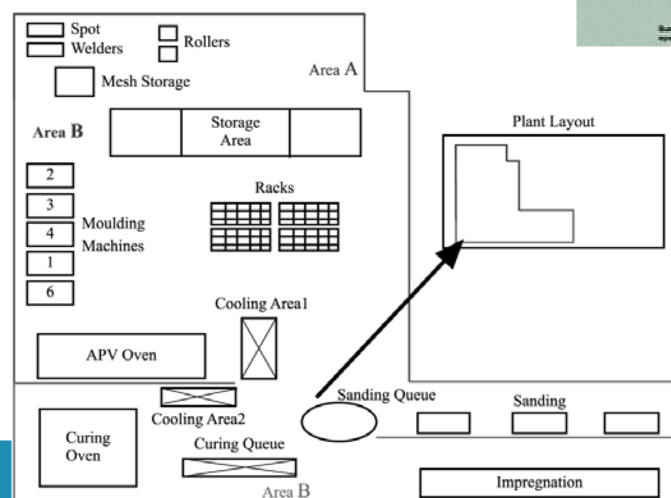
What is it about?

What is it about?

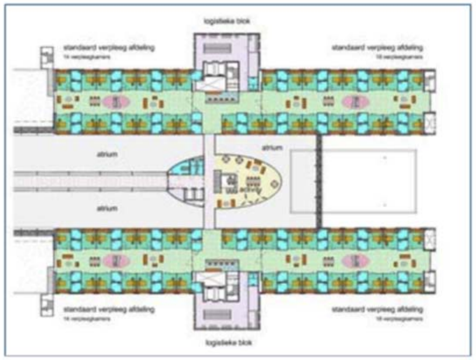
Layout = Physical arrangement of facilities in “space”

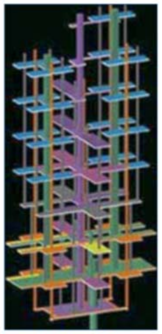




Layout optimization

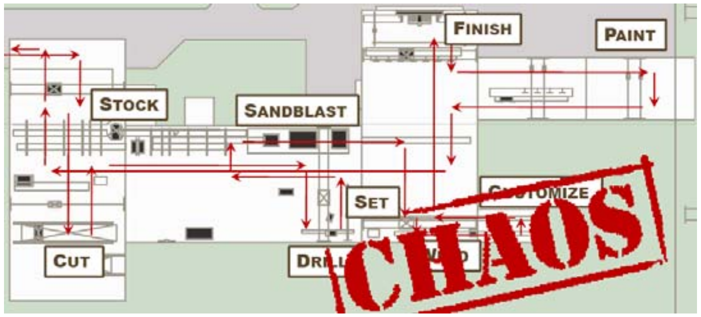
“green grass” approach





improvement


Paus Adriaan VI college



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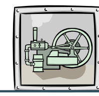
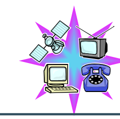
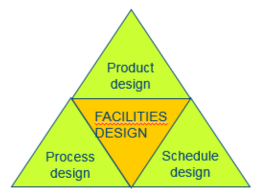
Some horror stories

An **engine manufacturer** was planning to develop a new site. The facilities planners and architects were designing facilities for the site. Decisions had **not** been made concerning which products would be off-loaded to the new site, nor what effect the off-load would have on requirements for moving, protection, storing, and controlling material. 	An **electronics manufacturer** was planning to develop a new site. The facilities planners and architects were designing the first building for the site. **No** projections of space and throughput had been developed since decisions had not been made concerning the occupant of the building. 
A **manufacturer of automotive equipment** acquired the land for a new manufacturing plant. The manufacturing team designed the layout, and the architect began designing the facility **before** the movement, protection, storage and control system was designed. 	A **distributor of sporting apparel** built a new site for its warehouse and office buildings. The layout looked nice, and was very people- and nature-friendly. The only thing the architects overlooked was that the docks were **not** only supposed to serve the small shipping vans, but also were supposed to receive the large suppliers' trucks. 
An **aerospace-related manufacturer** implemented **group technology** in its process planning and converted to manufacturing cells in a machining department. No analyses had been performed to determine queue or flow requirements. Subsequent analyses showed the manufacturing cells were substantially less efficient as a result of their impact on movement, protection, storage and control of work-in-process. 	

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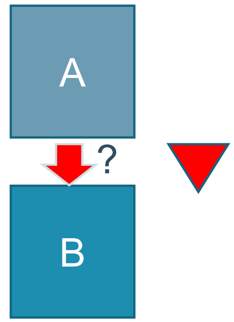
What to do first: layout or MH?



Common practice is to start with the "layout" and to design the material handling system afterwards

but MH decisions will seriously affect the layout

- centralized vs decentralized storage of WIP, tools, …
- fixed path versus variable path handling
- unit load planned
- degree of automation used in handling
- control of physical load characteristics

also movements, throughput, … and operations will affect the layout

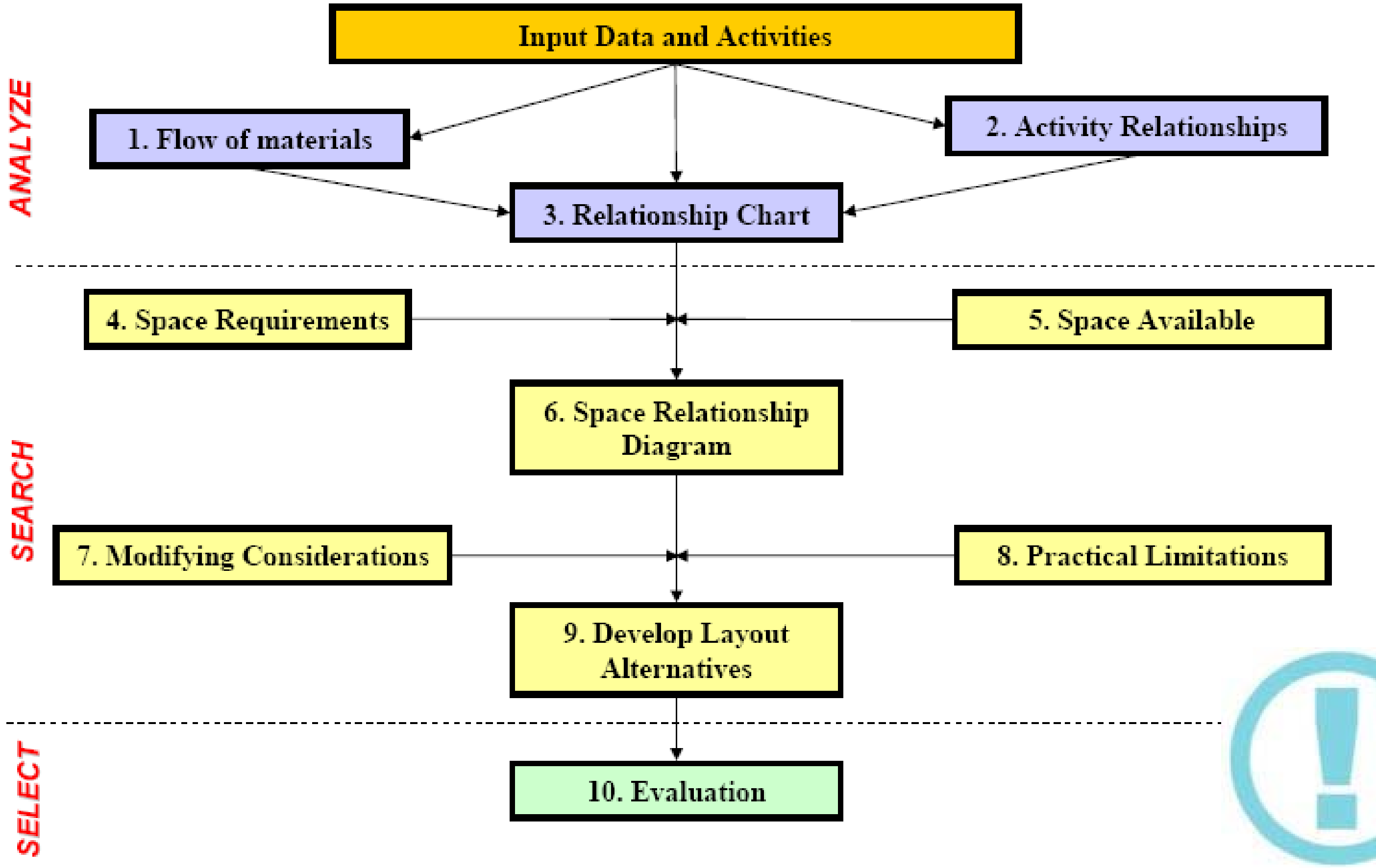
- requirements for space, equipment, personnel, …
- degree of proximity

Iterations, long term view, common sense and good *communication* needed !!
The layout and the handling system should be (re)designed ***simultaneously*** !

Note: Layout changes may have considerable *organizational impact* !!!

How to tackle a layout problem?

SLP (Systematic layout planning - Muther)

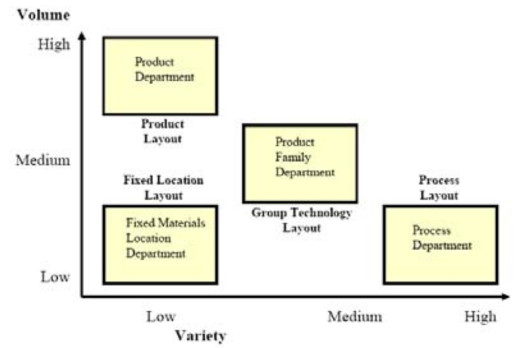


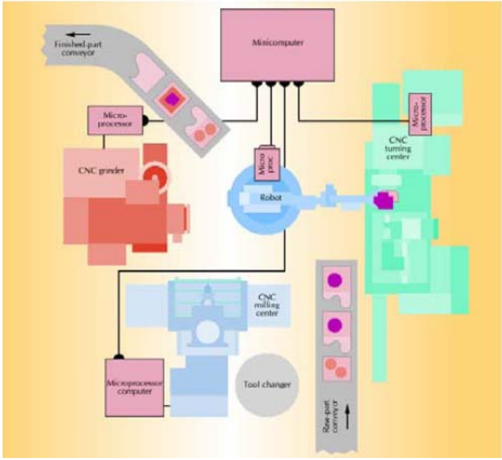
Layout types

4 basic types of departments (and layouts)

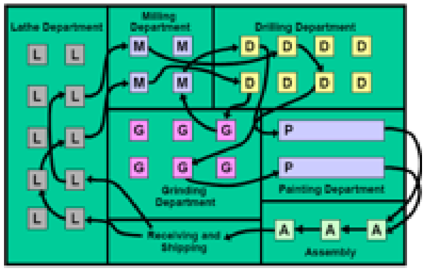
- ***Process Department***
  - Functionally arranged
  - Like processes are grouped
- ***Product***
  - Production line
- ***Project***
  - Large and hard-to-move items
- ***Product Family***
  - Produces a "family" of similar products

- Hybrids also exist

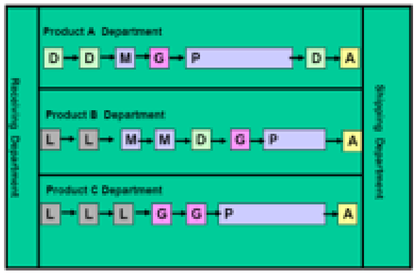




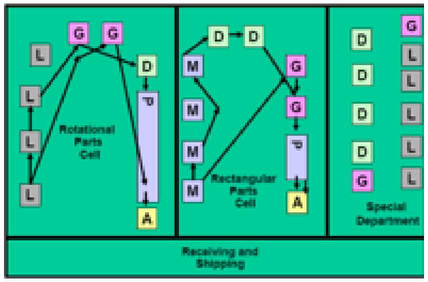
Process layout



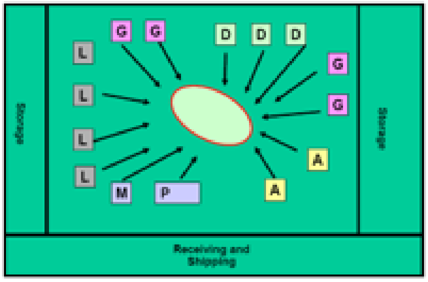
Product layout

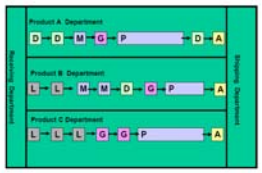


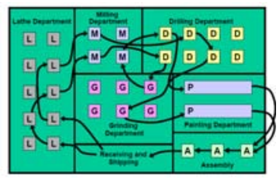
Product family or cellular layout



Project layout







Characteristics	Product layout	Process layout
Throughput time		
Work in process		
Skill level		
Product flexibility		
Demand flexibility		
Machine utilization		
Worker utilization		
Reliability		
Unit production cost		

What layout type(s) do you typically find in ... ?

- *An automobile assembly plant*
- *A chemical processing plant*
- *A hospital*
- *An aircraft manufacturing plant*
- *A mechanical work shop*

Flows

"<u>What</u>" is flowing, in say

In a factory, e.g. automotive plant

In a service organization, e.g. hospital

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Flow patterns

Within work stations

Within departments

Between departments

Within work stations

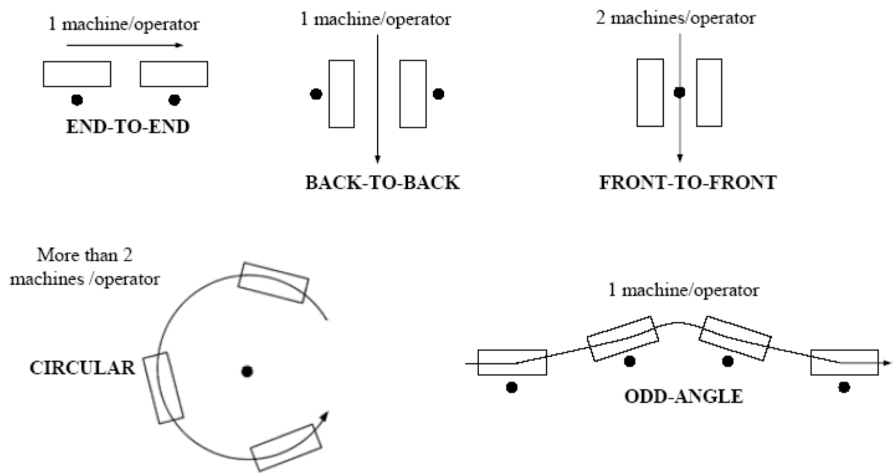
Flow patterns within workstations

Motion studies and ergonomics considerations are important in establishing the flow within workstations which should be:

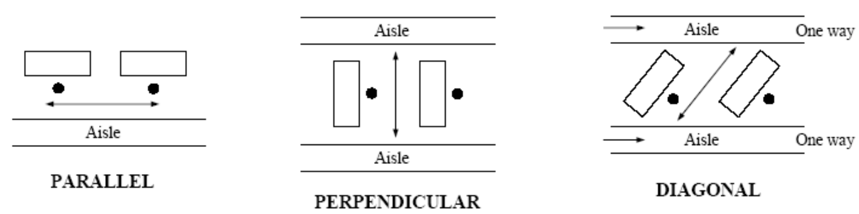
- **Simultaneous**: coordinated use of hands, arms and feet.
- **Symmetrical**: coordination of movements about the center of the body.
- **Natural**: movements are continuous, curved, and make use of momentum.
- **Rhythmical and Habitual**: flow allows a methodological and automatic sequence of activities. It should reduce mental, eye and muscle fatigue, and strain.

Flow patterns within departments

Within departments



- In a process department, little flow should occur between workstations within departments. Flow occurs between workstations and aisles.



Dependent on:

interactions among workstations

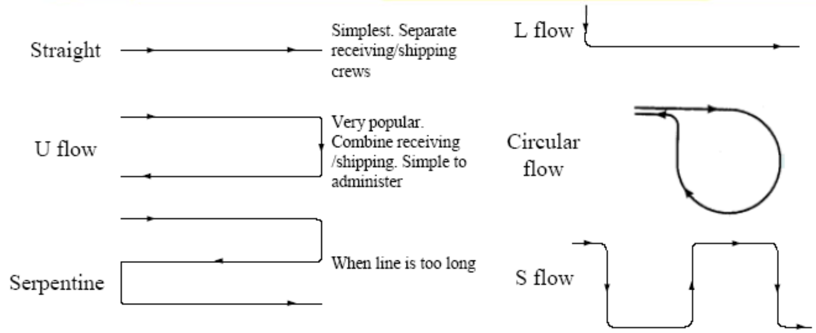
available space

size of materials

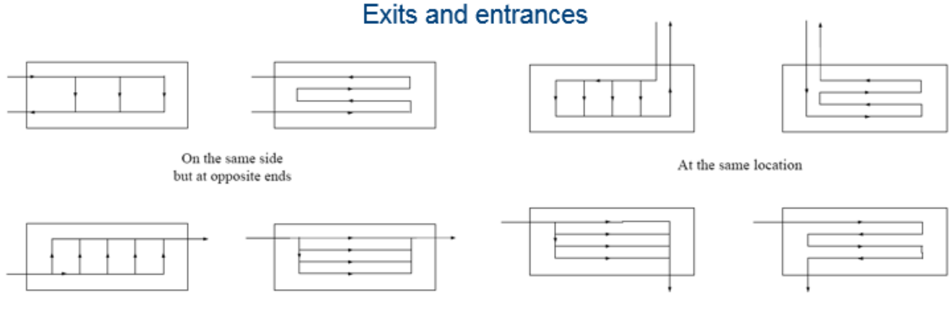
Between departments

Flow between departments

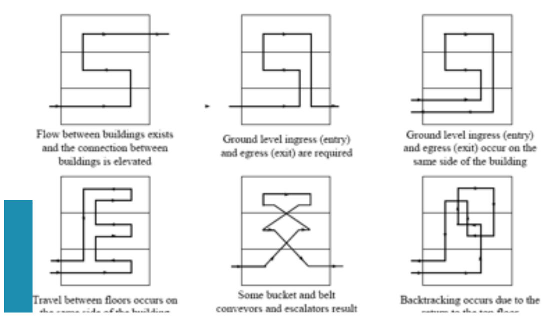
- Flow between departments is often used to evaluate flow within a facility.
- Flow typically is a combination of the basic horizontal flow patterns shown below.
- An important consideration in combining the flow patterns is the location of the entrance (receiving department) and exit (shipping department).



Exits and entrances



Vertical flow paths

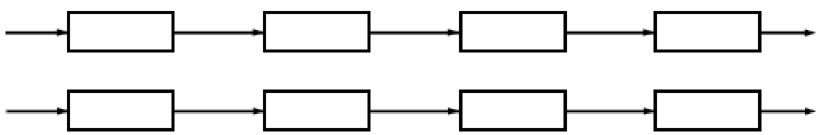


Flow planning

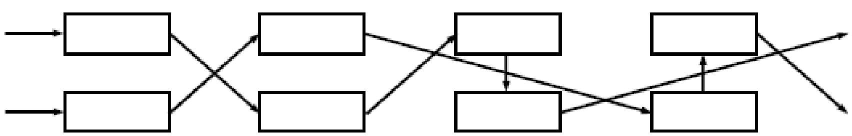
Planning effective flow involves combining the above patterns with adequate aisles to obtain progressive movements from origin to destination.

An effective flow can be achieved by maximizing directed flow paths, reducing flow, and minimizing the costs of flow.

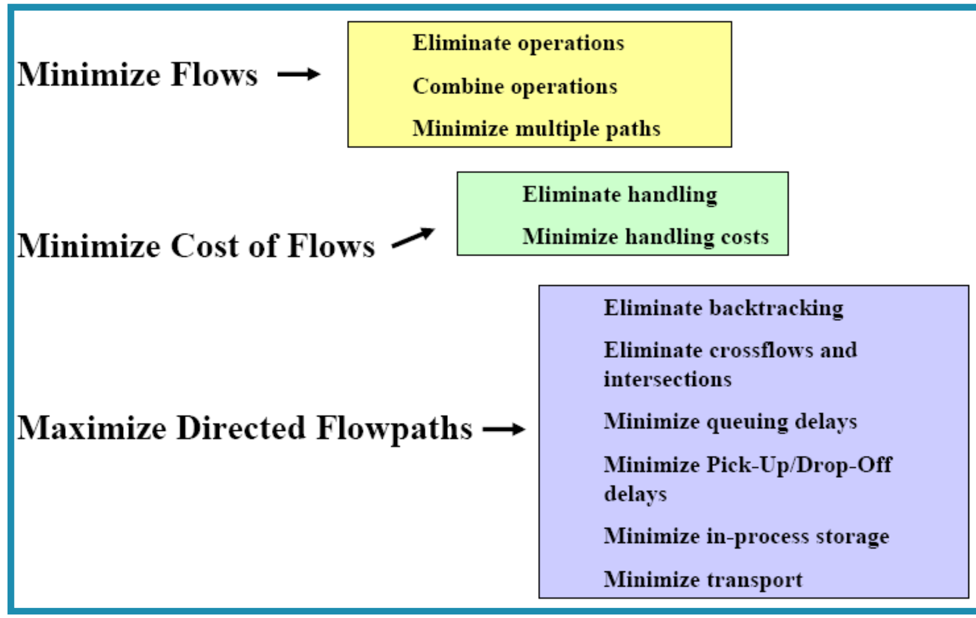
A directed flow path is an uninterrupted flow path progressing directly from origin to destination: the figure below illustrates the congestion and undesirable intersections that may occur when flow paths are interrupted.



Uninterrupted flow paths

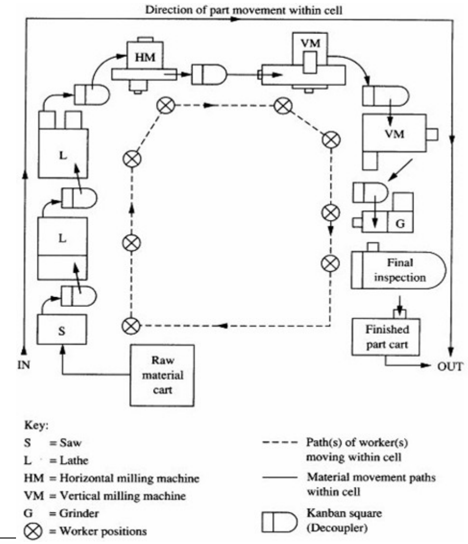


Interrupted flow paths



Flow analysis

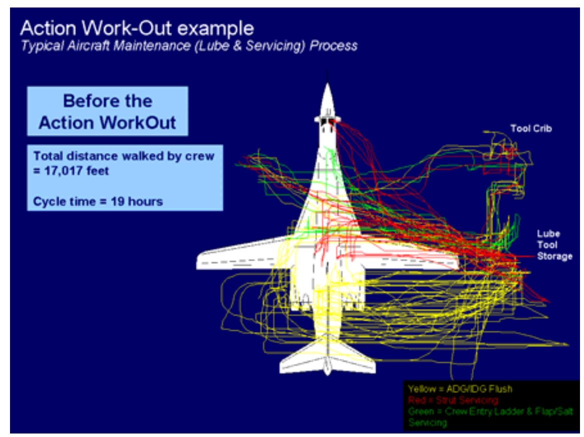
Mapping



See also previous chapter

Date: 9-30-02 Location: Graves Mountain
Analyst: TLR Process: Apple Sauce

Step	Operation	Transport	Inspect	Delay	Storage	Description of process	Time (min)	Distance (feet)
1	●					Unload apples from truck	20	
2		●				Move to inspection station		100 ft
3			●			Weigh, inspect, sort	30	
4		●				Move to storage		50 ft
5					●	Wait until needed	360	
6		●				Move to peeler		20 ft
7	●					Apples peeled and cored	15	
8					●	Soak in water until needed	20	
9	●					Place in conveyor	5	
10		●				Move to mixing area		20 ft
11			●			Weigh, inspect, sort	30	
	Page 1 0f 3					Total	480	190 ft



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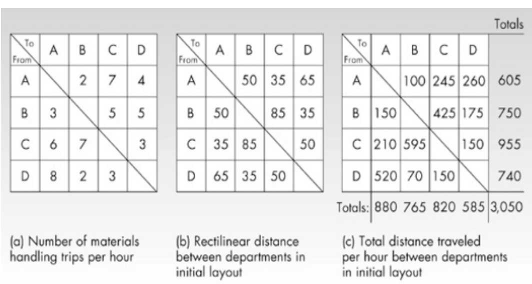
“Measuring” flow/relationships

From-to matrix

- Quantitative view
- Objective data
- Flow ~ meters
- Optimum
  - = min distance travelled

Relationship chart/diagram

- Qualitative view
- Subjective data
- Expressing preferences about “closeness” of departments
- Optimum
  - = max closeness



To / From	A	B	C	D
A		2	7	4
B	3		5	5
C	6	7		3
D	8	2	3	

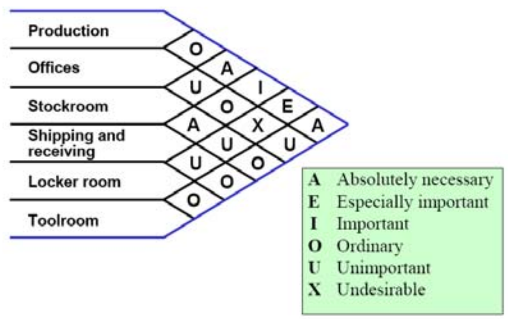
(a) Number of materials handling trips per hour

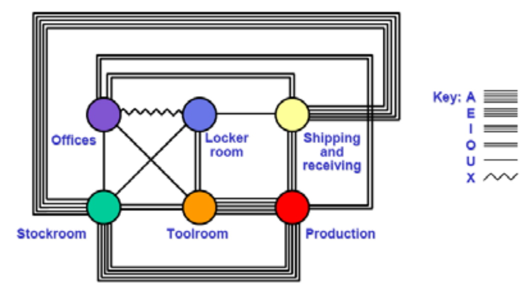
To / From	A	B	C	D
A		50	35	65
B	50		85	35
C	35	85		50
D	65	35	50	

(b) Rectilinear distance between departments in initial layout

To / From	A	B	C	D	Totals
A		100	245	260	605
B	150		425	175	750
C	210	595		150	955
D	520	70	150		740
Totals:	880	765	820	585	3,050

(c) Total distance traveled per hour between departments in initial layout





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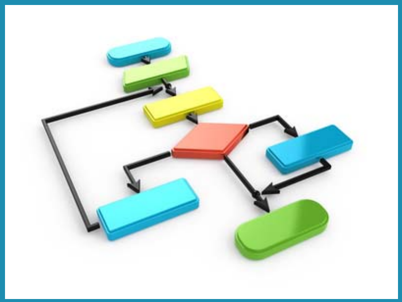
Algorithms



Types of algorithms

Many differences (classification schemes) ...

- Different starting points
  - *construction vs improvement heuristics*
- Different type of input required
  - <u>qualitative and/or quantitative input</u>
- Different layout representation
  - *discrete (grid) vs continuous*
- Different objective function
  - *minimum total distance vs maximum adjency score*
- Different userfriendliness
  - *pen & paper, COTS software, math programming, …*

Here:

- Traditional math programming approach (QAP)
- Graph theoretic approach
- Computer aided algorithms (block layouts)
- Newer developments

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Mathematical programming models for construction site layout problems

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12th Global Conference on Sustainable Manufacturing

Production Layout Optimization for Small and Medium Scale Food Industry

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(1) Traditional math programming approach

QAP (Quadratic Assignment Problem)

$$\min \sum_{i=1}^{M}\sum_{k=1}^{M}\sum_{j=1}^{N}\sum_{l=1}^{N} f_{ik} d_{jl} x_{ij} x_{kl}$$

$$\textit{subject to}$$

$$\sum_{j=1}^{N} x_{ij} = 1 \quad \textit{for } i = 1,\ldots M$$

$$\sum_{i=1}^{M} x_{ij} \leq 1 \quad \textit{for } j = 1,\ldots N$$

$$x_{ij} \in \{0,1\}$$

where

- i=1,2,… m unit departments
- j=1,2, … n unit locations
- f_{ik}=relationship between departments i and k
- d_{jl}=distance between locations j and l
- x_{ij}=1 if department i is located in location j, =0 otherwise

QSCP

(Quadratic Set Covering Problem)

$$\text{Minimize} \sum_{i=1}^{M} \sum_{k=1}^{M} \sum_{j=1}^{L(i)} \sum_{l=1}^{L(k)} f_{ik} x_{ij} x_{kl} d(j_i, l_k)$$

subject to

$$\sum_{j=1}^{L(i)} x_{ij} = 1 \text{ for } i = 1, M$$

$$\sum_{i=1}^{M} \sum_{j=1}^{L(i)} b_{ijn} x_{ij} \leq 1 \text{ for } n = 1, N$$

$$x_{ij} \in \{0,1\}$$

Based on candidate locations for departments

LAP

(Linear Assignment Problem)

$$\text{Minimize} \sum_{i=1}^{M} \sum_{k=1}^{M} x_{ij} \left(\sum_{k=1}^{K} f_{ik} d_{jk} \right)$$

subject to

$$\sum_{j=1}^{N} x_{ij} = 1 \text{ for } i = 1, M$$

$$\sum_{i=1}^{M} x_{ij} \leq 1 \text{ for } j = 1, N$$

$$x_{ij} \geq 0$$

Takes into account distances to fixed points (eg I/O)

(2) Graph theoretical approach

Based on1-to-1 relation between block layout and planar graph

Nodes represent departments

Arcs represent relationships

Graph is **planar** if it can be drawn in 2-D without arcs crossing.

Maximally planar if no additional arcs can be added

Many different methods exist !

- node insertion
- hexagonal adjacency graphs (SPIRAL), deltahedron heuristic, Green-Al Hakim, Leung, …

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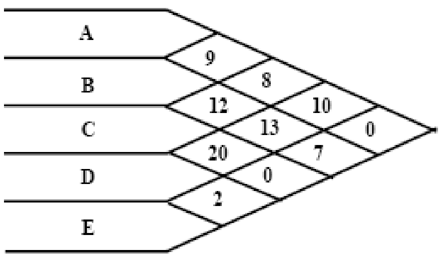
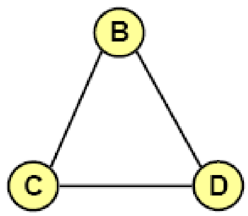
Example: node insertion method



1. Select pair with largest weights (C-D)
2. Select 3rd node (B) as one with largest combined weight with (C-D)

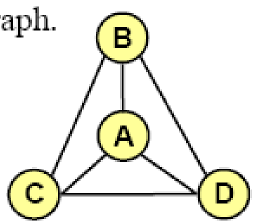
	C	D	TOT
A	8	10	18
B	12	13	25
E	0	2	2



3. Determine which dept, has highest weight with respect to depts. already placed.

	B	C	D	TOT
A	9	8	10	27
E	7	0	2	9

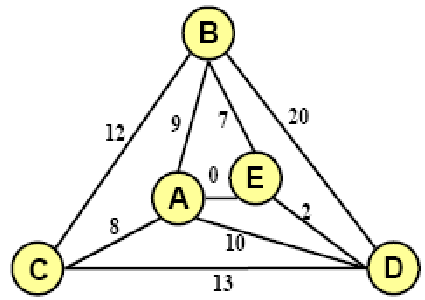
A is placed next into center "face" of graph.



Where should E go?

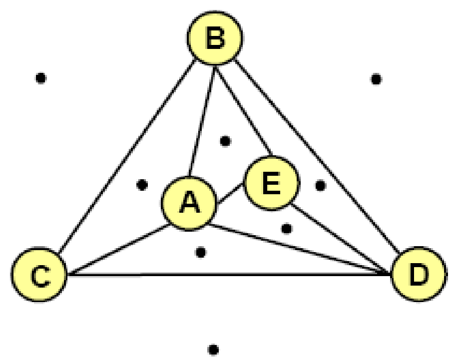
- Check each face of the graph.
- Node 5 is inserted at the A-B-D face

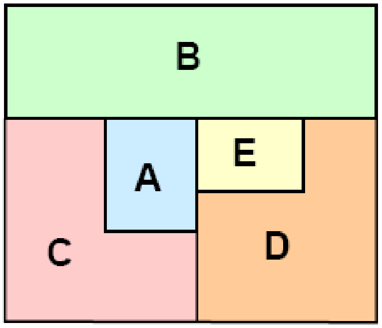
	FACES		
	A-B-C	A-C-D	A-B-D
5	7	2	9



Total Score =81

(Maximum)

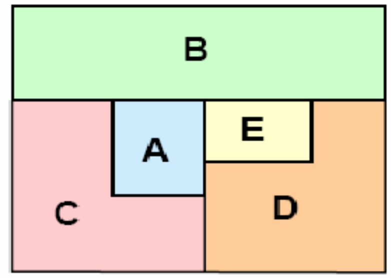




(3) CAL (computer aided layout)

Basics

Block layouts



Scoring

- Distance based scoring
  - Volume-distance product
- Adjacency based scoring
- Multi-objective scoring

$$\min z^{distance} = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij} c_{ij} d_{ij}$$

$$\max z^{adjacency} = \frac{\sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij} x_{ij}}{\sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij}}$$

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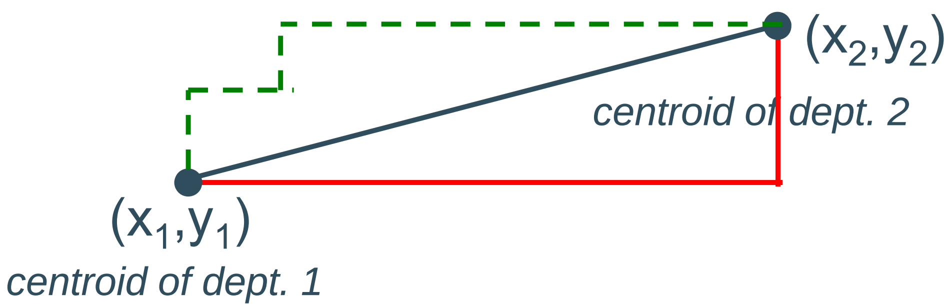
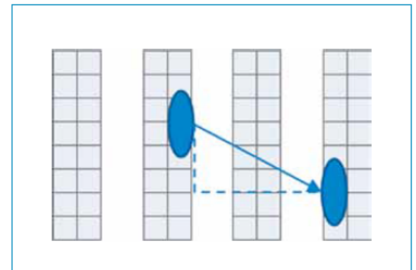
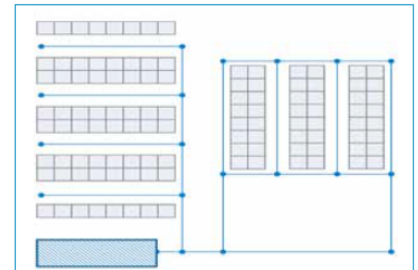
Illustration: distance-based scores




Manhattan en Euclidis


knooppuntmethode

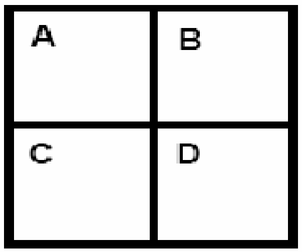
$$d_{rectilinear,Manhattan} = |x_1 - x_2| + |y_1 - y_2|$$

$$d_{euclidean} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

$$d_{chebyshev} = \max\{|x_1 - x_2|, |y_1 - y_2|\}$$

Illustration: distance and adjency scoring

Example – Each dept. is 100' x 100'



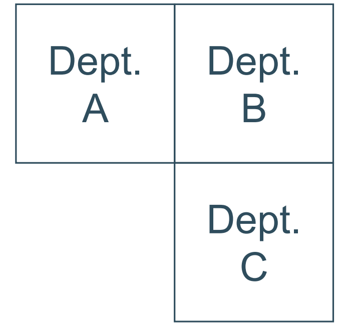
	A	B	C	D
A	-	2	4	6
B	6	-	8	10
C	4	8	-	7
D	2	10	0	-

FLOW

	A	B	C	D
A	-	100	100	200
B	100	-	200	100
C	100	200	-	100
D	200	100	100	-

DISTANCE

	A	B	C	D	TOT
A	-	200	400	1200	*1800*
B	600	-	1600	1000	*3200*
C	400	1600	-	700	*2700*
D	400	1000	0	-	*1400*
					9100



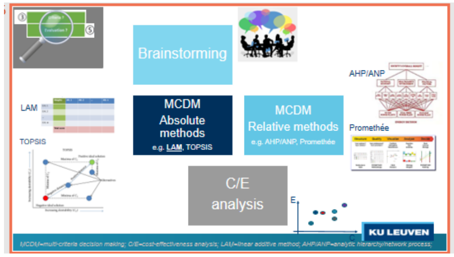
Corner adjacency: e.g. A-C
Side-to-side adjacency: e.g. A-B

Border-to-border distance:
e.g. A-B: 0 and A-C: 1

Relationship	If adjacent	If not adjacent
A	100	0
E	50	0
I	25	0
O	5	0
U	0	0
X	-100	0

other conversions possible !

Illustration: multi-objective scoring



			A		B		C		D	
	Factor	*Weight*	*Rating*	*Score*	*Rating*	*Score*	*Rating*	*Score*	*Rating*	*Score*
1	MH Cost	30	8	240	7	210	10	300	10	300
2	Space Utilization	30	7	210	6	180	6	180	10	300
3	Safety	10	9	90	10	100	7	70	5	50
4	Flexibility	5	7	35	8	40	9	45	6	30
5	Material Flow	25	10	250	9	225	9	225	7	175
	Total	100		825		755		820		855

- Useful in group evaluation situations
- Must decide on weights
- While totally subjective, allows for fair comparisons

Can be solved (partly)

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“Oldie” illustration : ALDEP

(Automated Layout DEsign Program – Seehof&Evans, 1967)

Construction algorithm

Example

Required space

Dept.	Name	Area (ft^2)
1	receiving	12000
2	milling	8000
3	press	6000
4	drilling	12000
5	assembly	8000
6	plating	12000
7	shipping	12000

Requested closeness

Dept/Dept	1	2	3	4	5	6	7
1	-	E	O	I	O	U	U
2		-	U	E	I	I	U
3			-	U	U	O	U
4				-	I	U	U
5					-	A	I
6						-	E

Extra information

Scoring

Adjacency score, based on

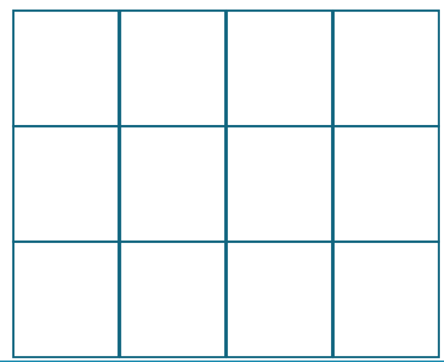
relation	A	E	I	O	U	X
value	64	16	4	1	0	-1024

Areas

Unit square = 6000 ft^2

⇨ dept1: 2, dept2: 1, dept3: 1, dept4: 2, dept5: 1, dept6: 2, dept7: 2 unit squares

Building = 4 by 3 unit squares



Algorithm parameter settings

Minimum closeness ranking = E

Sweep width = 1

Algorithm

initial set of candidates = {1, 2, 3, 4, 5, 6, 7}

first randomly selected department = 3

Minimum closeness ranking

set of candidates with E or higher relation with 3 = { }

set of candidates = {1, 2, 4, 5, 6, 7}

second randomly selected department = 7

set of candidates with E or higher relation with 7 = {6}

third selected department = 6

set of candidates with E or higher relation with 6 = {5}

fourth selected department = 5

set of candidates with E or higher relation with 5 = { }

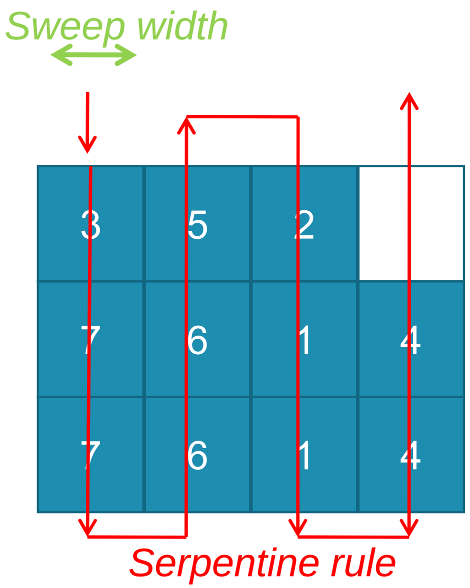
set of candidates = {1, 2, 4}

fifth randomly selected department = 2

set of candidates with E or higher relation with 2 = {1, 4}

sixth randomly selected department = 1

last selected department = 4



Layout score

		ideally		currently	
relation	value	#	score	#	score
A	64	1	64	1	64
E	16	3	48	3	48
I	4	5	20	4	16
O	1	3	3	2	2
U	0	9	0	3	0
X	-1024	0	0	0	0
			135		**130**

relative score (%) **96%**

3	5	2	
7	6	1	4
7	6	1	4

Dpt/Dpt	1	2	3	4	5	6	7
1	-	E	O	I	O	U	U
2		-	U	E	I	I	U
3			-	U	U	O	U
4				-	I	U	U
5					-	A	I
6						-	E

CAL: why (not) ?

Why ?

- Reasonable effort
- Often satisfactory performance
- (though also often limited quality)
- “Easy” to use in practice

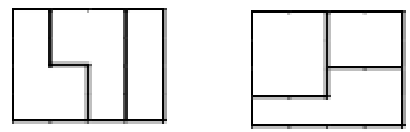
BUT …

- deterministic approach
- often single objective
- only tangibles (quid e.g. safety ?)
- linearity of MH cost (few exceptions)
- rectilinear distances
- scoring methods
- initial layout bias
- obstacles
- “choices” within algorithms: DOE !!☺
- scale effects and shapes

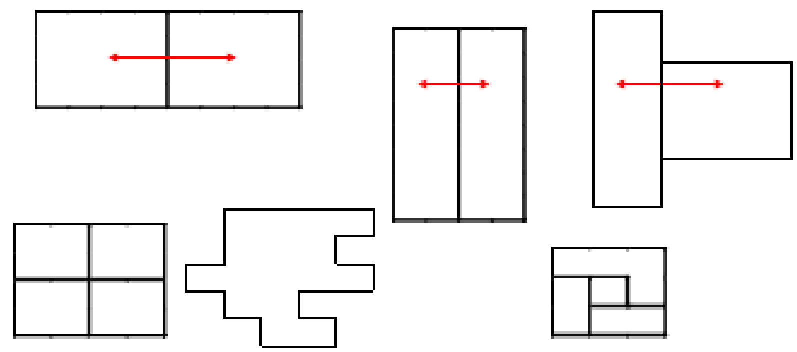
...

scale effects, grid size, ….

Aldep example (sweep width)



department area & shape



Solution: use cohesion score, SER, …

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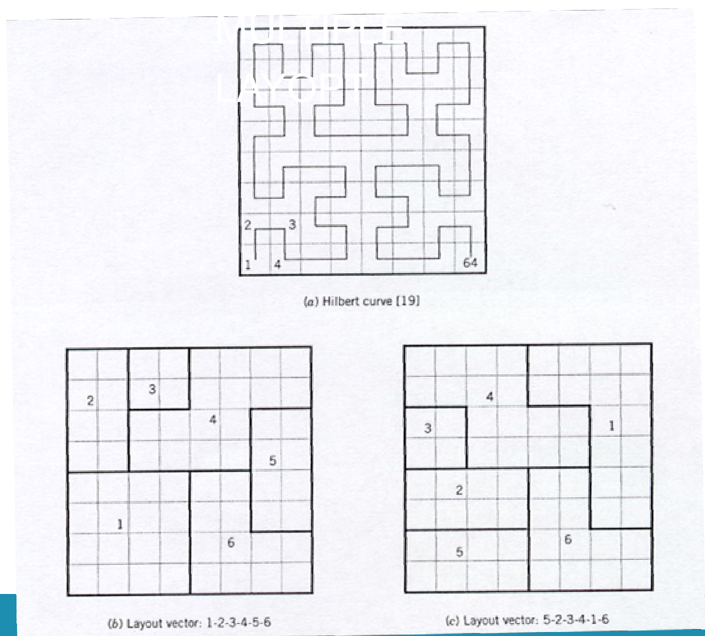
(4) new(er) developments

Space filling curves (SFC)

Use of the SFC in improvement or construction algorithms

Different types of SFC exist

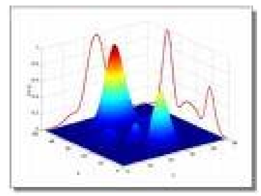
Also for multi-level

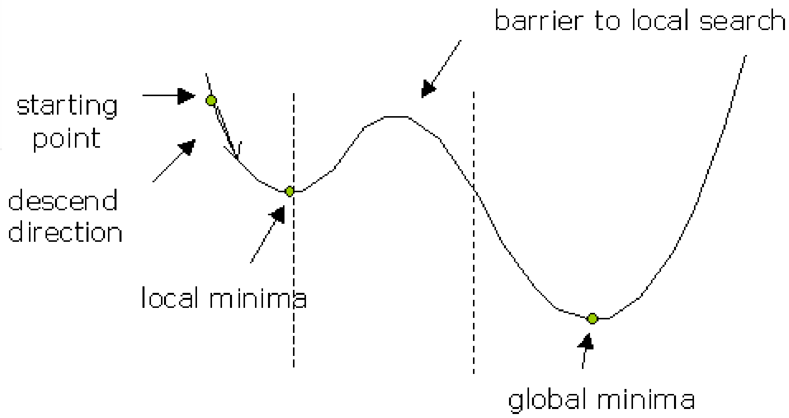


Genetic algorithms (GA)

Based on observation that survival-of-the-fittest (SOF) principle in nature may be used in solving decision-making, optimization and machine learning problems

GA work with a family of solutions (population) from which a "next" generation of better solutions is obtained.





Stopping rule: if no noticeable improvement is obtained in the last x trails.

Consider: **simulated annealing**

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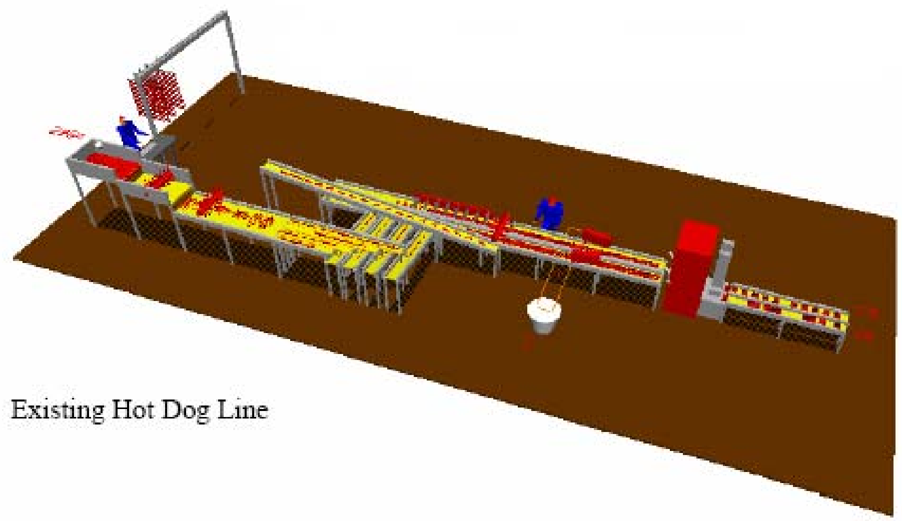
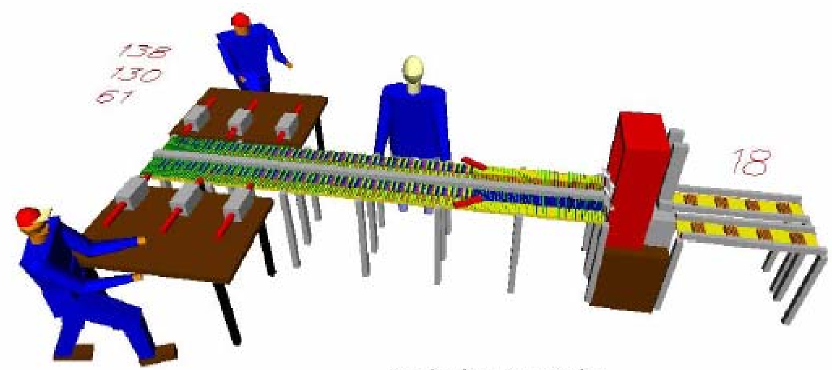
Why (not) newer algorithms ?

- On-going research, often not limited to layout optimization
- Can avoid drawbacks of myopic old algorithms
- Many different approaches possible
- Experience most often required
- Programming skills needed – Some commercial packages exist

Don't forget about simulation !

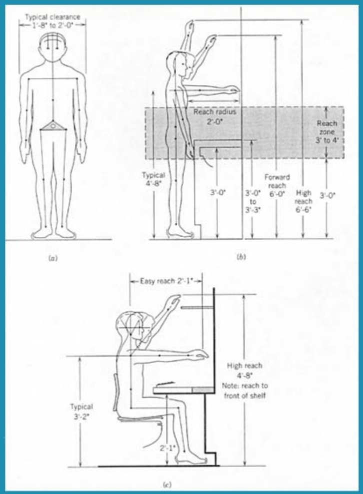


Existing Hot Dog Line



Revised Hot Dog Line

Space requirements



What is it about?

Blocks 4 and 5 of SLP

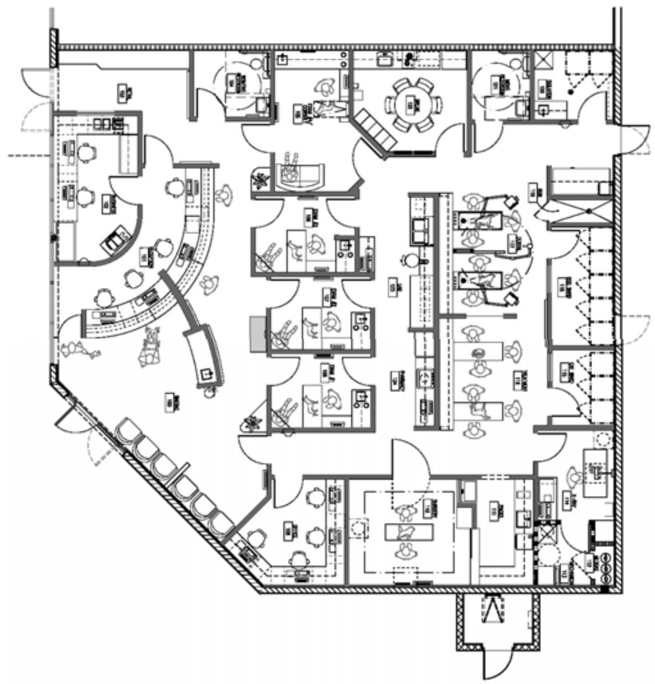
Perhaps the most difficult aspect of facility plan

Large amounts of uncertainty

- Technology changes
- Demand forecasts
- Changing product mix
- Parkinson's Law – things will fill available space
- New designs (pull systems, decentralized storage, etc)

Generally use "bottom-up" approach

- Define workstation spaces
- Define departmental spaces (with aisle allowances)



Workstation space

Equipment Footprint

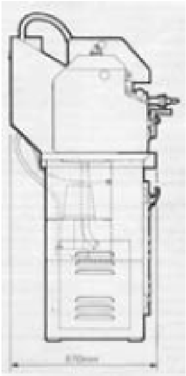
- Machine Travel
- Machine Maintenance
- Plant Services

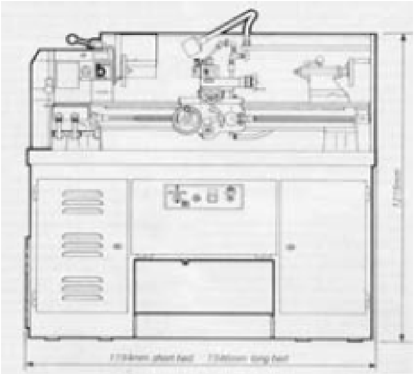
Material

- Inbound and store
- In-process
- Outbound
- Waste and Scrap
- Tools Fixtures
- Can depend on system

Personnel

- The operator
- Material handling
- Ingress/Egress min (30”-42”)





Try to:

- Eliminate long and awkward reaches
- Make work efficient
- Minimize manual handling
- Maximize operator safety, comfort and productivity

Departemental space
Rather complex !

- Not the simple sum of workstation spaces
  - Many items are shared from workstation to workstation
- Add aisle allowances:

If the largest load is:	**Aisle Allowance % ***
< 6 ft^2	5-10%
6-12 ft^2	10-20%
12-18 ft^2	20-30%
>18 ft^2	30-40 %

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Aisle planning

Objective: <u>**Promote Flow**</u>

Two Types:

– Departmental Aisles (previous section)

– Main Aisles

Tradeoff

– Congestion versus Wasted Space

Principles:

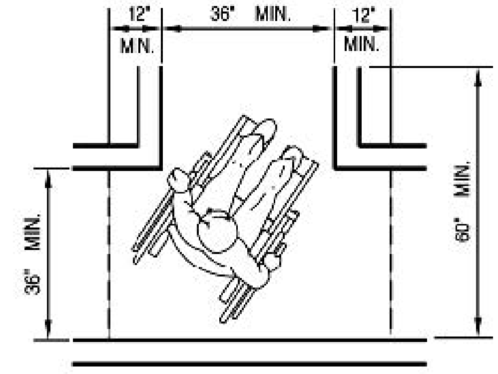
– Avoid curves, jogs, non-right-angle intersections

– Aisles should be straight and lead to doors

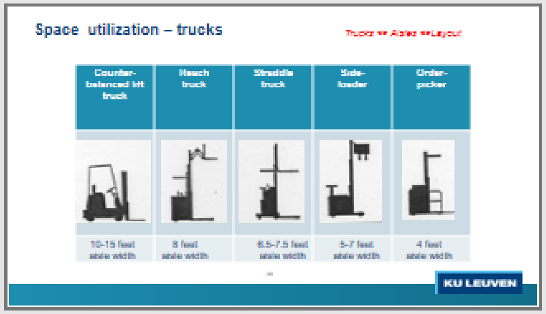
– Avoid aisles along outer wall of bldg. Unless for entry/exit

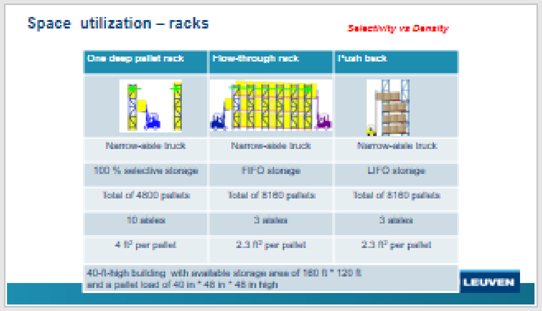
– Don't forget to consider column spacing!

Type of Flow	Aisle Width (ft)
Tractors	12
3-ton Forklift	11
2-ton Forklift	10
1-ton Forklift	9
Narrow Aisle Truck	6
Manual Platform truck	5
Personnel	3
Personnel with doors opening into aisle from one side	6
Personnel with doors opening into aisle from two sides	8



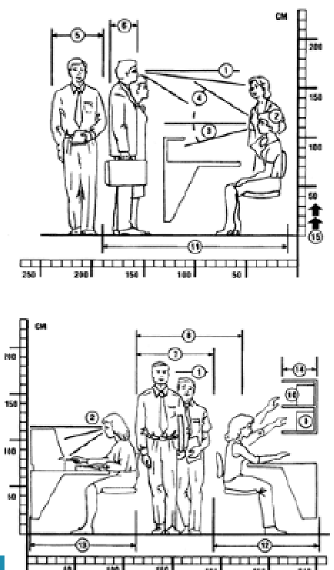
T–SHAPED SPACE FOR 180° TURNS



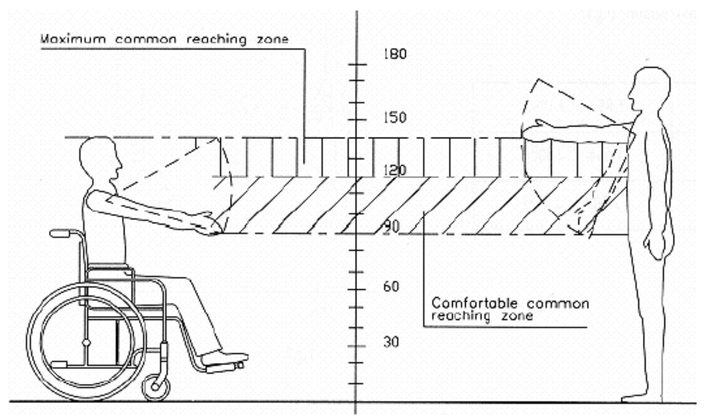


Personnel space requirements

- Greatly a function of owner philosophy
  - E.g. food services, office planning, health services, …
- Also
  - Barrier free compliance
  - Anthropometrics/Ergonomics



1. AVERAGE EYE HEIGHT STANDING
2. AVERAGE EYE HEIGHT SEATED
3. NATURAL ANGLE OF VISION
4. RANGE OF VISION
5. MAXIMUM BODY BREADTH
6. MAXIMUM BODY DEPTH
7. ONE - WAY PASSAGE - MIN
8. TWO - WAY PASSAGE - MIN
9. NORMAL REACH HEIGHT SEATED
10. EXTENDED REACH HEIGHT SEATED
11. WORKSTATION DEPTH - RECEPTION
12. WORKSTATION DEPTH MIN - MAX
13. V.D.U. WORKSTATION DEPTH MIN - MAX
14. SHELF / CABINET DEPTH
15. SCREEN HEIGHTS



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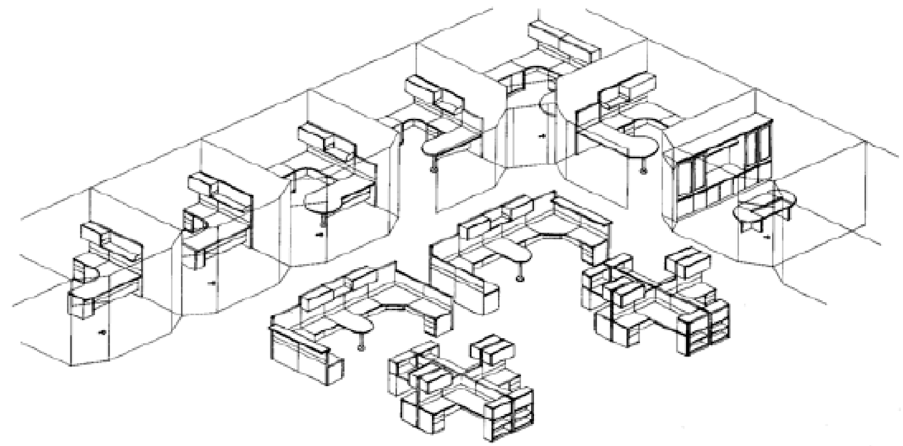
Parking lot design

- Number of automobiles
  - Need space for every 1.25 employees
  - 2-5 spaces per 100 cars for handicapped
- Space required for each
  - 7'x15' to 9.5'x19' for small/large cars
  - 12'x20' handicapped
  - Many tables available
- Available space and configuration
- Consider employee convenience (< 500')
- OSHA 1910.36 (.37) code for entrance/exits

Office planning

- Very challenging
- Everyone has opinions, views, likes/dislikes
- Most offices are combinations of open areas and private offices
- Collect activity data and determine objectives
- Companies provide complete office design and inventory mgmt services

Space Type	Sq. Feet.
Executive Office	250-400
Manager	80-110
Clerical	60-110
Conference Room	20-30 per person
Reception Area	125-300
File Room	7 per file cab.

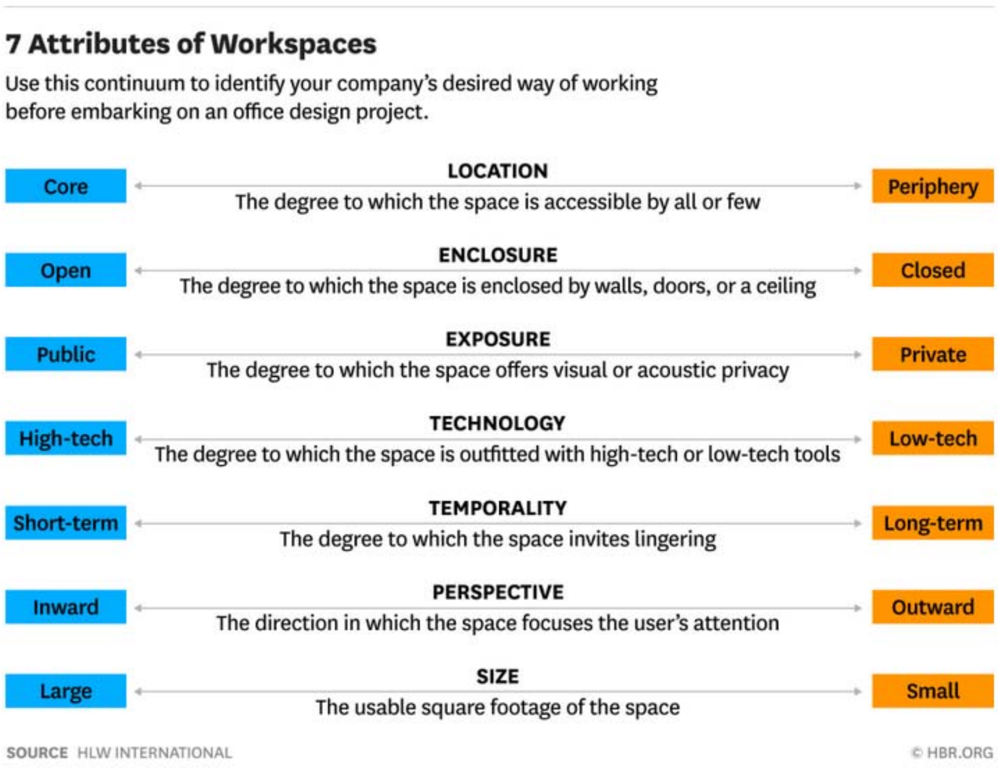


HOE HET OPEN KANTOOR MEE KAN LEIDEN TOT BURN-OUT

Wegbezuinigd: onze concentratie!

12 MAART 2016 | Van onze correspondent 'leven & werk' Eva Berghmans

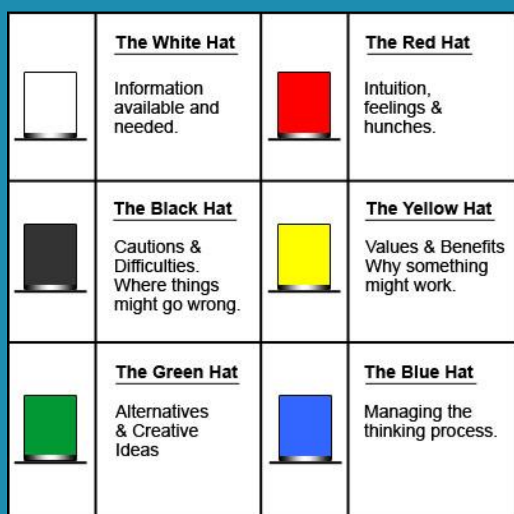
Het open kantoor is ruim en licht. Het belichaamt de nieuwe stijl van werken, maar is eigenlijk vaak ingegeven door besparingen. En de kakofonie van lawaai en de overdaad aan prikkels putten ons uit.



EXAMPLE

https://hbr.org/2016/05/7-factors-of-great-office-design

Stuff-to-think about



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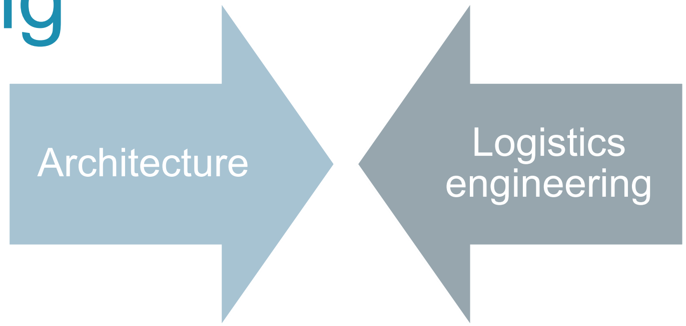
Layout, Flow and Wayfinding



Wayfinding

find destination + (confirmation under way)

Wayfinding – Wayshowing in hospitals

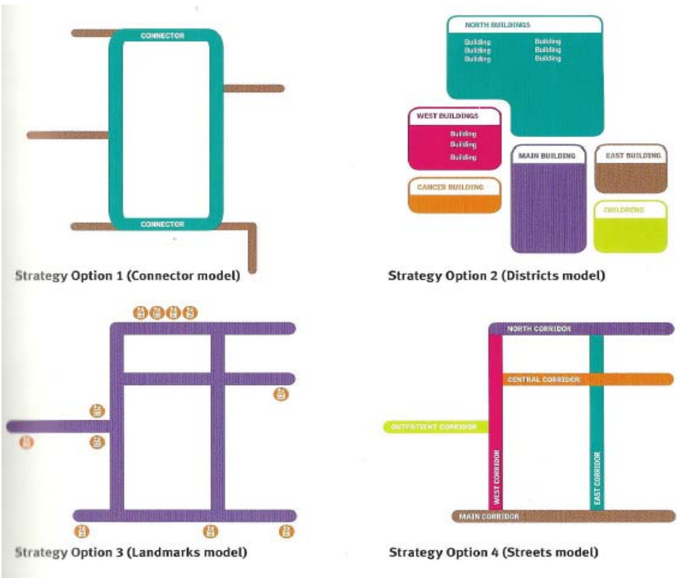
complex buildings/sites

stressed users, users with disabilities, …

Wayfinding should be designed for the first - time visitor because repeat visitors can use their past experiences for navigation (Lynch, 1960).

Wayfinding: architecture (“readable building”) – support (signage)

Basic choices



(Gibson, 2009)

Supporting signage

“Signage = art and science”

Static

colors: arrows and/or zones (progressive disclosure)

routes

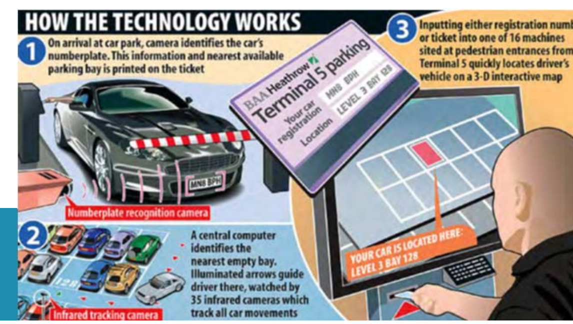
Dynamic

Information kiosks

Helpful technology

On-line router planner

“IoT”
(internet of things)



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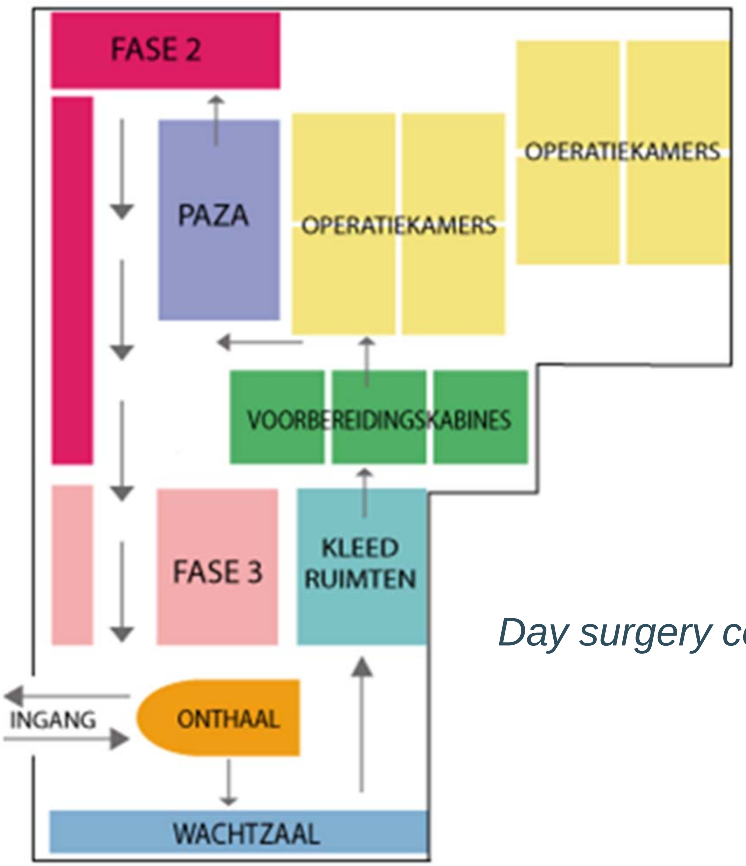
Layout and core business



Day surgery center

Central sterilization unit

EXAMPLE

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Wrap-up

Important conclusions

Layout decision making

types, concerns, interactions with MH, flows

Algorithms

developing a critical look

Space requirements

how to determine

Stuff-to-think about