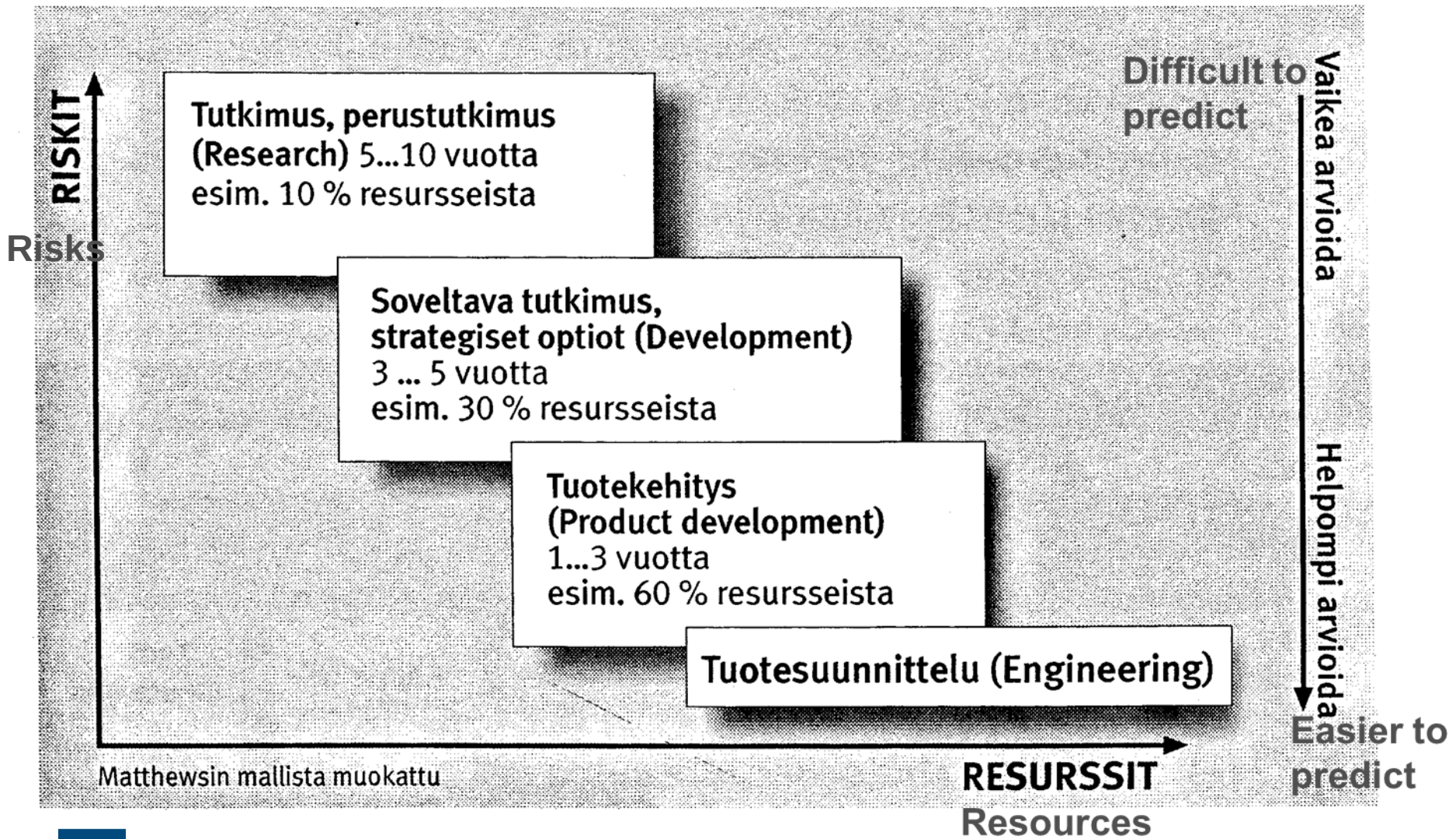


TKSUE100 MECHANICAL ENGINEERING DESIGN

Design Process



jamk.fi



Methods and tools

- SYSTEMATIC PRODUCT DEVELOPMENT
- INTEGRATED PRODUCT DEVELOPMENT
- SIMULTANEOUS ENGINEERING
- CONCURRENT ENGINEERING
- BENCHMARKING
- QUALITY FUNCTION DEPLOYMENT (QFD)
- HIGH DESIGN
- TEAM DESIGN
- VALUE ANALYSIS
- STANDARDIZATION
- MODULARIZATION
- PRODUCEABILITY ENGINEERING
- TRANSITION TO MANUFACTURING
- DESIGN FOR MANUFACTURABILITY (DFM)
- DESIGN FOR ASSEMBLY (DFA)
- DESIGN FOR "X" (DFX)
- CAD/CAE
- SIMULATION
- ADDITIVE MANUFACTURING (RAPID PROTOTYPING)



Product Lifecycle Management (PLM)

- Management of product data and design process with software
 - engineering
 - process planning
 - production planning
 - logistics
 - service and maintenance
- Product Data Management (PDM)
 - 3D-geometry
 - drawings
 - bill of materials
 - FEM -analysis
 - assembly instructions
 - project plans
 - NC -programs

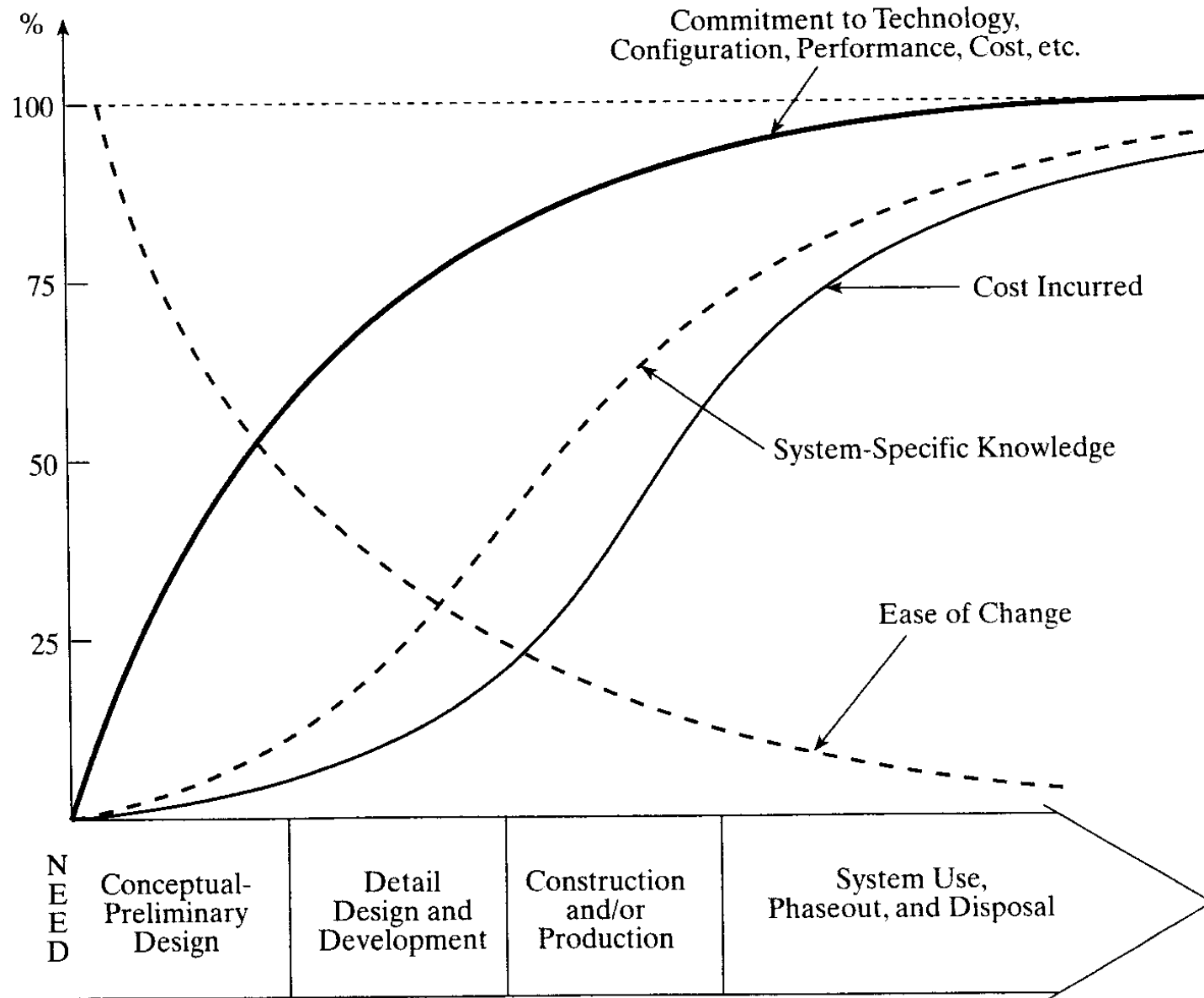


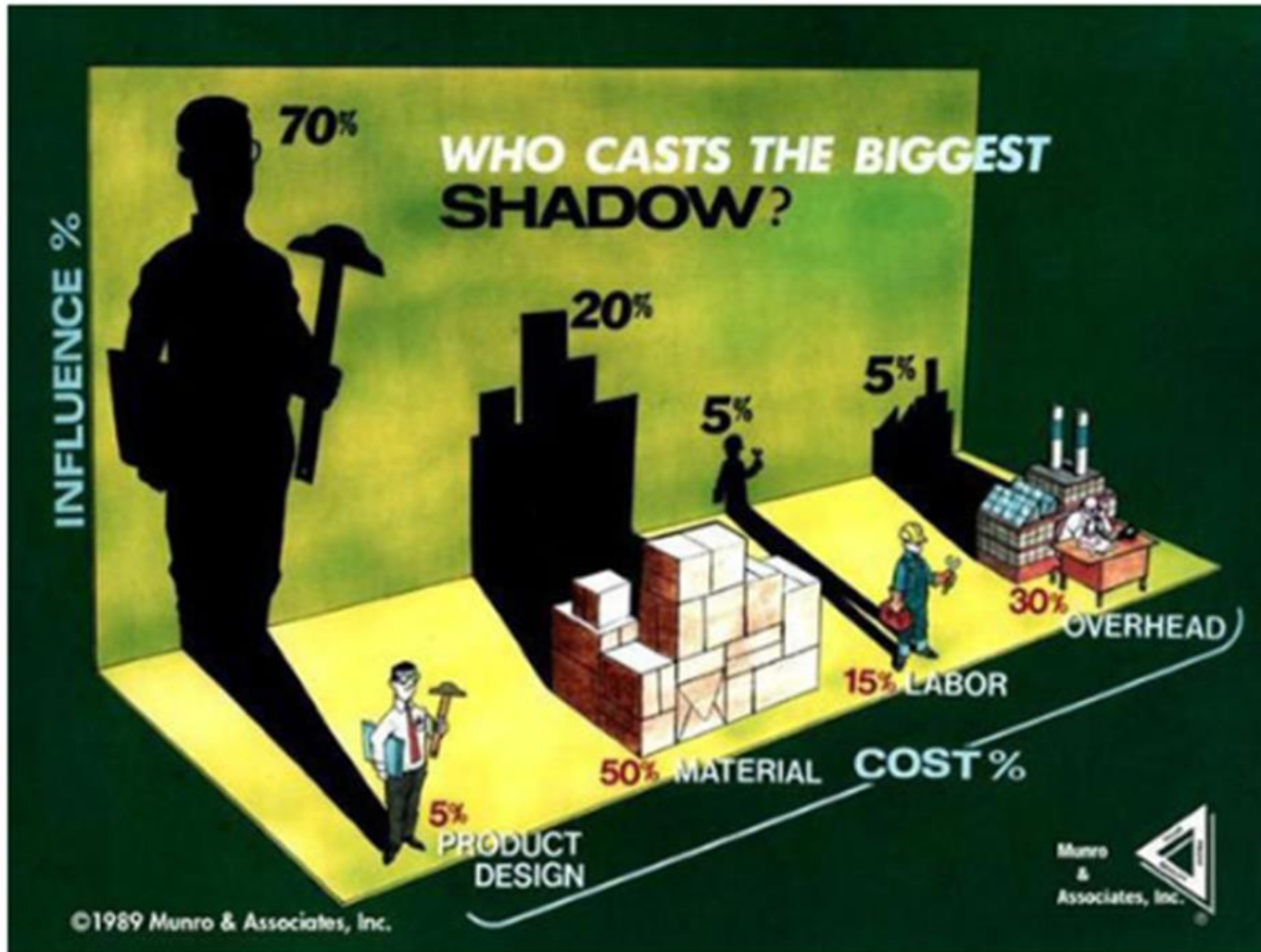
Product Life Cycle Assessment (LCA & LCC)

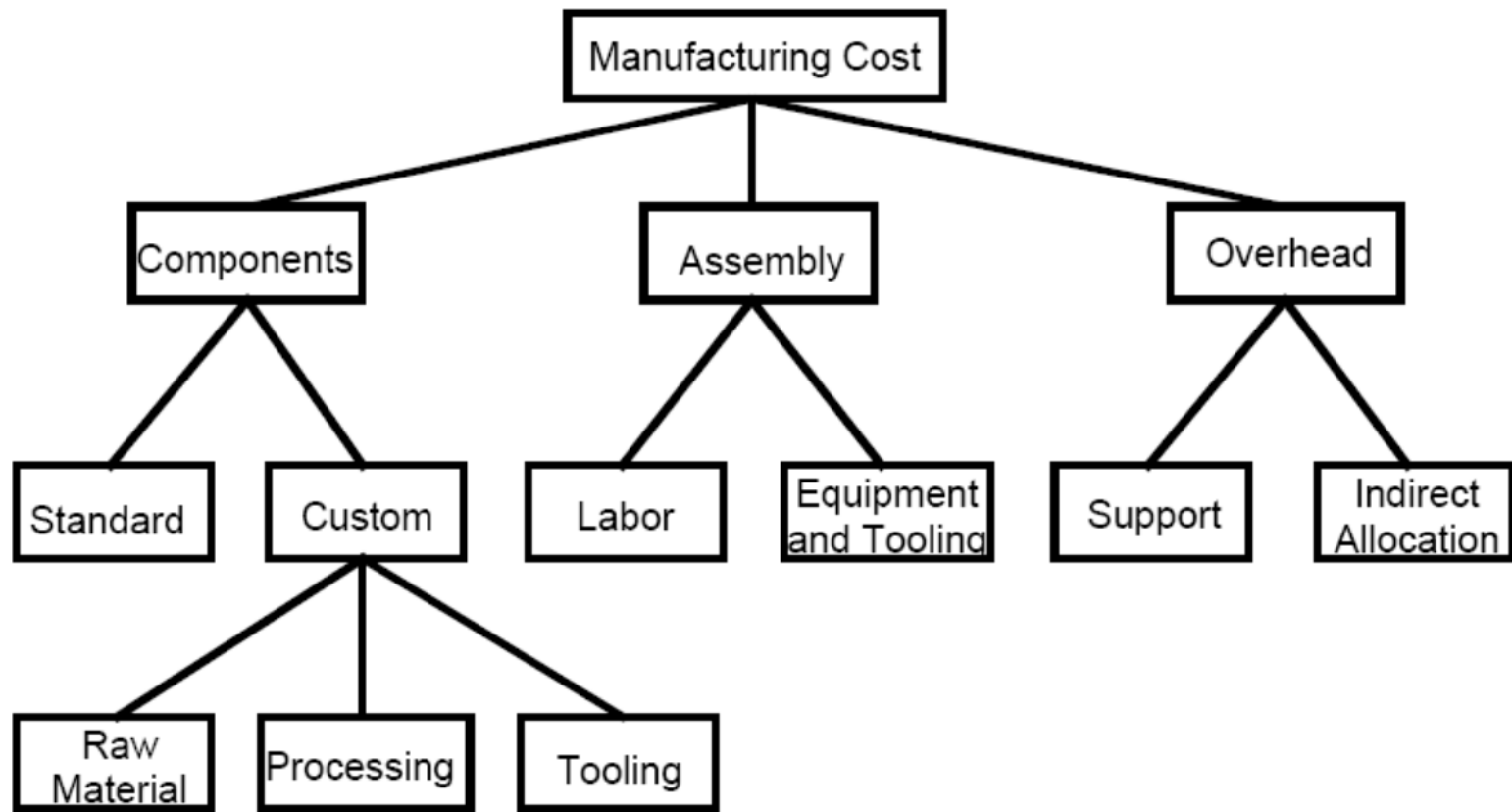
- Life Cycle Assessment (LCA)
 - environmental influence of a product (SFS-EN ISO 14040)
 - raw material production
 - manufacturing
 - supply
 - operation
 - disposal (recycling)
 - transportation between different phases
- Life Cycle Costs (LCC)
 - calculation of life cycle costs



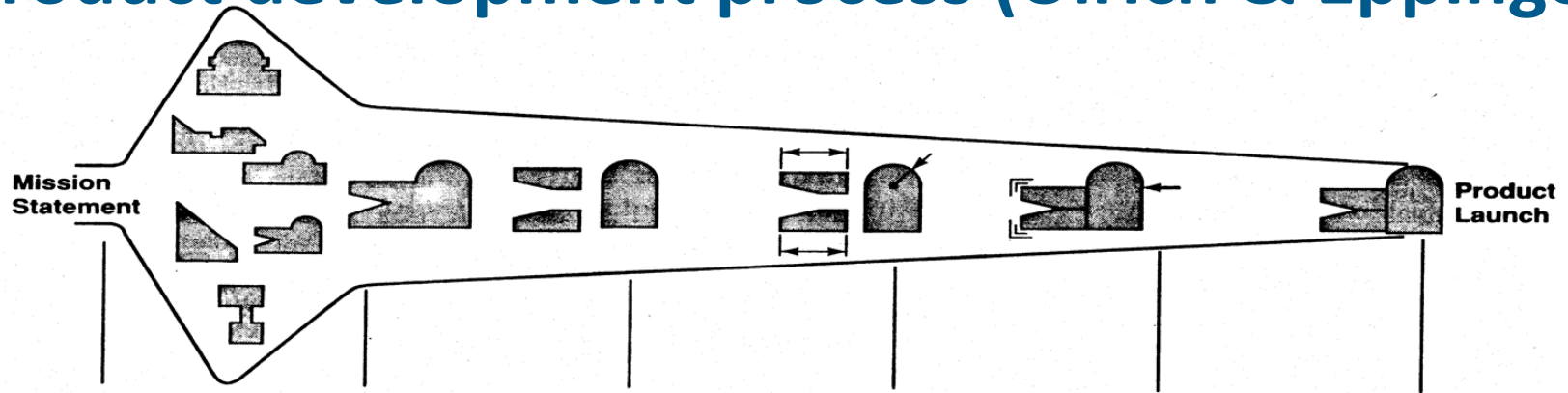
(Blanchard 1997)







Product development process (Ulrich & Eppinger)



Concept Development

Marketing

- Define market segments.
- Identify lead users.
- Identify competitive products.

Design

- Investigate feasibility of product concepts.
- Develop industrial design concepts.
- Build and test experimental prototypes.

Manufacturing

- Estimate manufacturing cost.
- Assess production feasibility.

Other Functions

- Finance: Facilitate economic analysis.
- Legal: Investigate patent issues.

System-Level Design

- Develop plan for product options and extended product family.

- Generate alternative product architectures.
- Define major sub-systems and interfaces.
- Refine industrial design.

- Identify suppliers for key components.
- Perform make-buy analysis.
- Define final assembly scheme.

- Finance: Facilitate make-buy analysis.
- Service: Identify service issues.

Detail Design

- Develop marketing plan.

- Define part geometry.
- Choose materials.
- Assign tolerances.
- Complete industrial design control documentation.

- Define piece-part production processes.
- Design tooling.
- Define quality assurance processes.
- Begin procurement of long-lead tooling.

Testing and Refinement

- Develop promotion and launch materials.
- Facilitate field testing.

- Do reliability testing, life testing, and performance testing.
- Obtain regulatory approvals.
- Implement design changes.

- Facilitate supplier ramp-up.
- Refine fabrication and assembly processes.
- Train work force.
- Refine quality assurance processes.

- Sales: Develop sales plan.

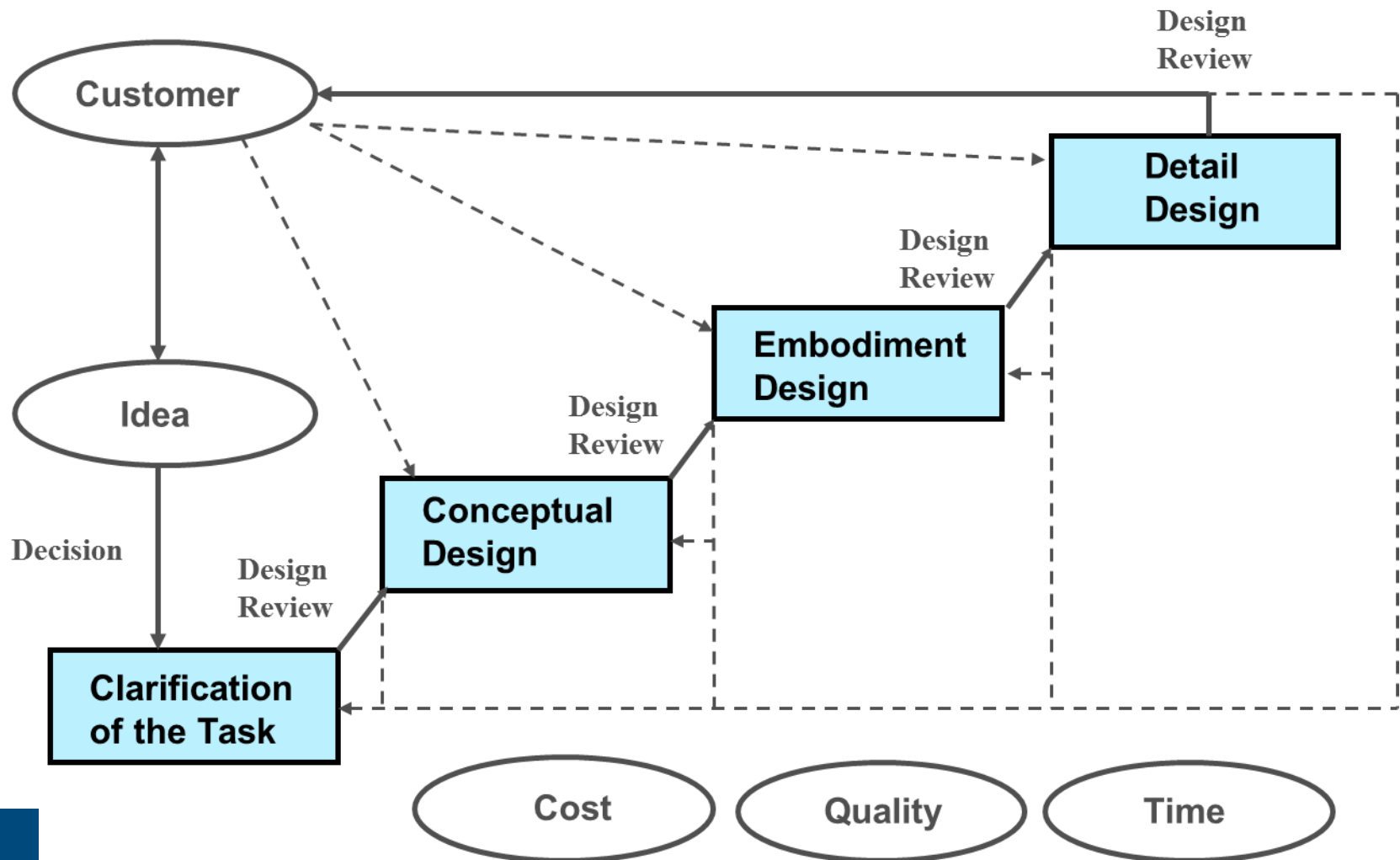
Production Ramp-Up

- Place early production with key customers.

- Evaluate early production output.

- Begin operation of entire production system.

Design process (Pahl&Beitz)

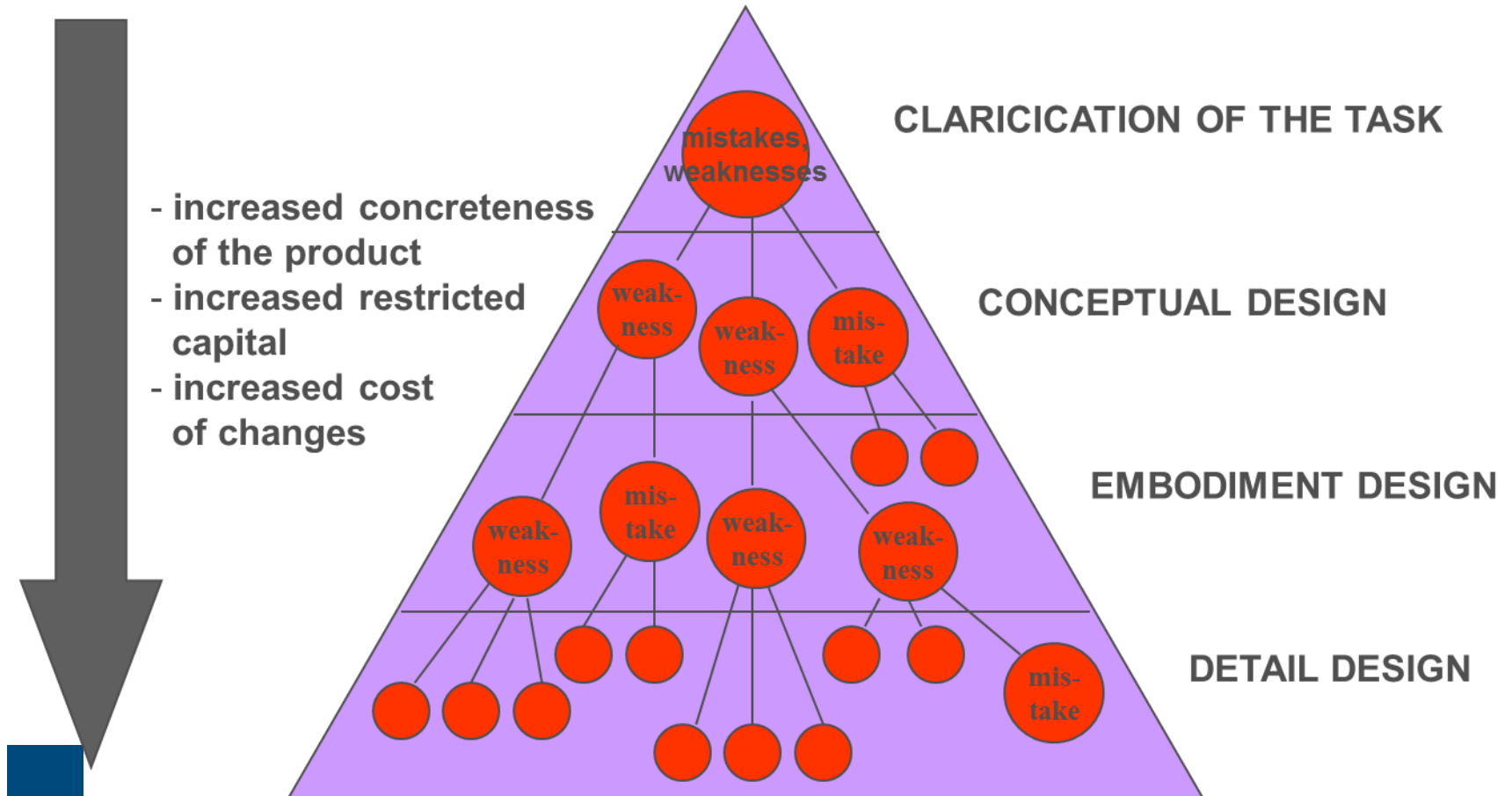


Clarification of the task

- analysis of the task
 - core of the problem
 - needs of the customer and technological possibilities
 - (hidden) wishes and expectations
 - validity of requirements
- common target to participants of the project
- the task must be defined as completely and clearly as possible (enough time and money)



Importance of the clarification



Clarification of the task

- result: preliminary product specification
- methods and tools
 - market research
 - study of production possibilities
 - feasibility studies
 - risk analysis
 - patent surveys
 - specification (list of requirements)
 - QFD: house of quality
 - question and check lists



List of requirements

- company's internal view of functional, technical and cost requirements of the product and fulfilled wishes
- made by the product development team
- both qualitative and quantitative objects and requirements
- concrete values



List of requirements

- classification of requirements
 - fixed requirements (FR)
 - must be met in every circumstances (e.g. technical performance)
 - minimum requirements (MR)
 - the limit of the requirement must be achieved, exceeding the limit is desirable (e.g. minimum efficiency, maximum noise level)
 - desires (D)
 - needs to be taken in consideration if possible



List of requirements

Main character	Examples
Geometry	Size, height, width, length, number,...
Kinematics	Direction of motion, speed, acceleration,...
Forces	Intensity and direction of force, weight, deformation,...
Energy	Power, efficiency, friction, pressure, temperature,...
Material	Physical and chemical properties of input and output products...
Signal	Input and output signals, control,...
Safety	Operation, occupational and environmental safety,...
Ergonomics	Man-machine interface, industrial design,...
Manufacture	Possible limitations, method, quality requirements,...
Inspection	Measurement and test possibilities, standards,...
Installation	Special orders, assembly, foundations,...
Transportation	Limitations of cranes, method of transport,...
Operation	Noiselessness, area, circumstances,...
Maintenance	Number of services, controls, adjustments,...
Recycling	Reprocessing, dissipation,...
Cost	Allowable manufacturing cost, investments,...
Deadlines	End of product development, delivery time,...

Conceptual design

- generalization of the problem
- function structure
- solution principles for subfunctions
- combining and firming up of subsolutions into concept variants
- (prototypes and tests)
- methods and tools
 - check lists
 - ideation methods
 - decision-making tools

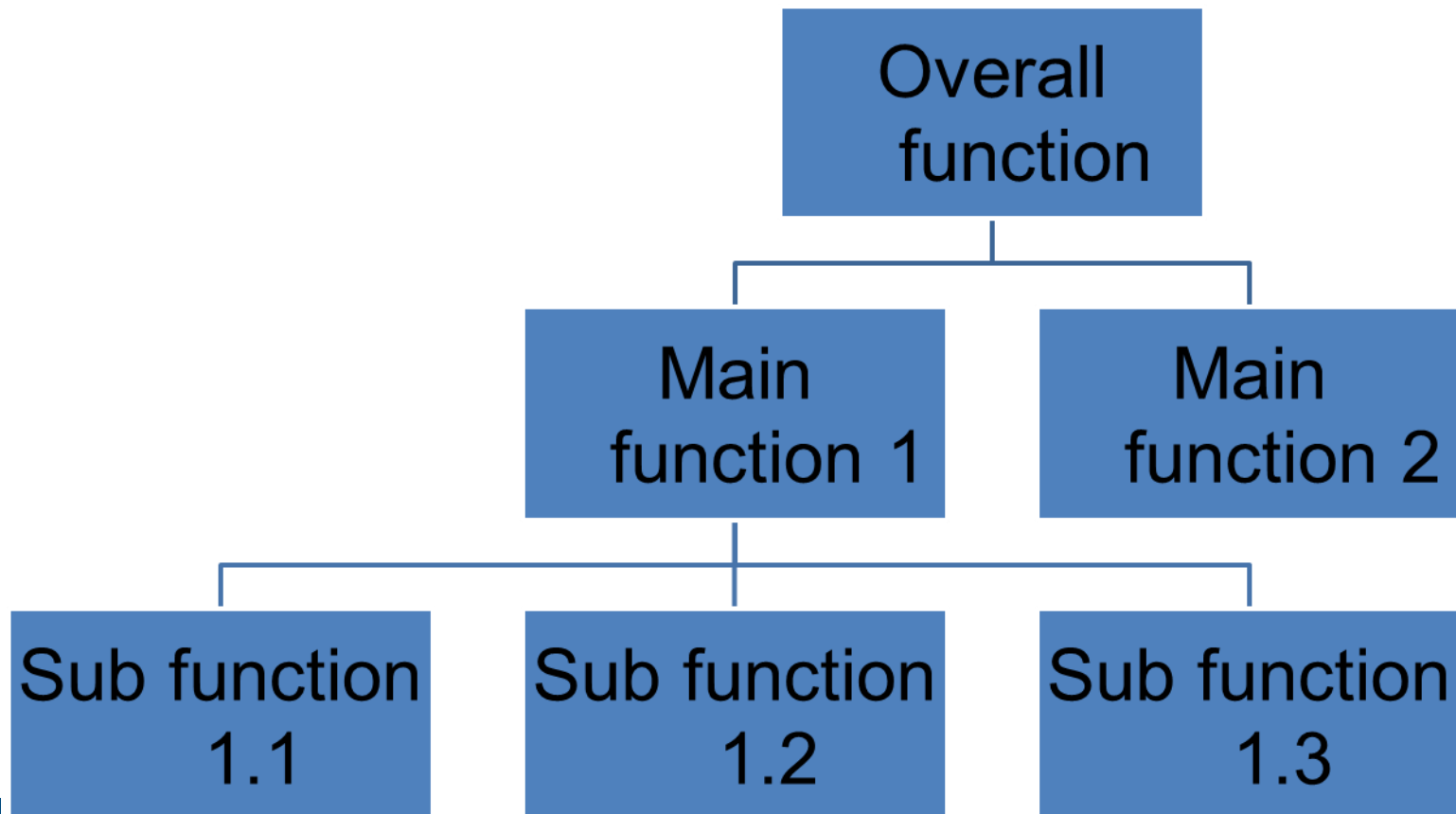


Conceptual design

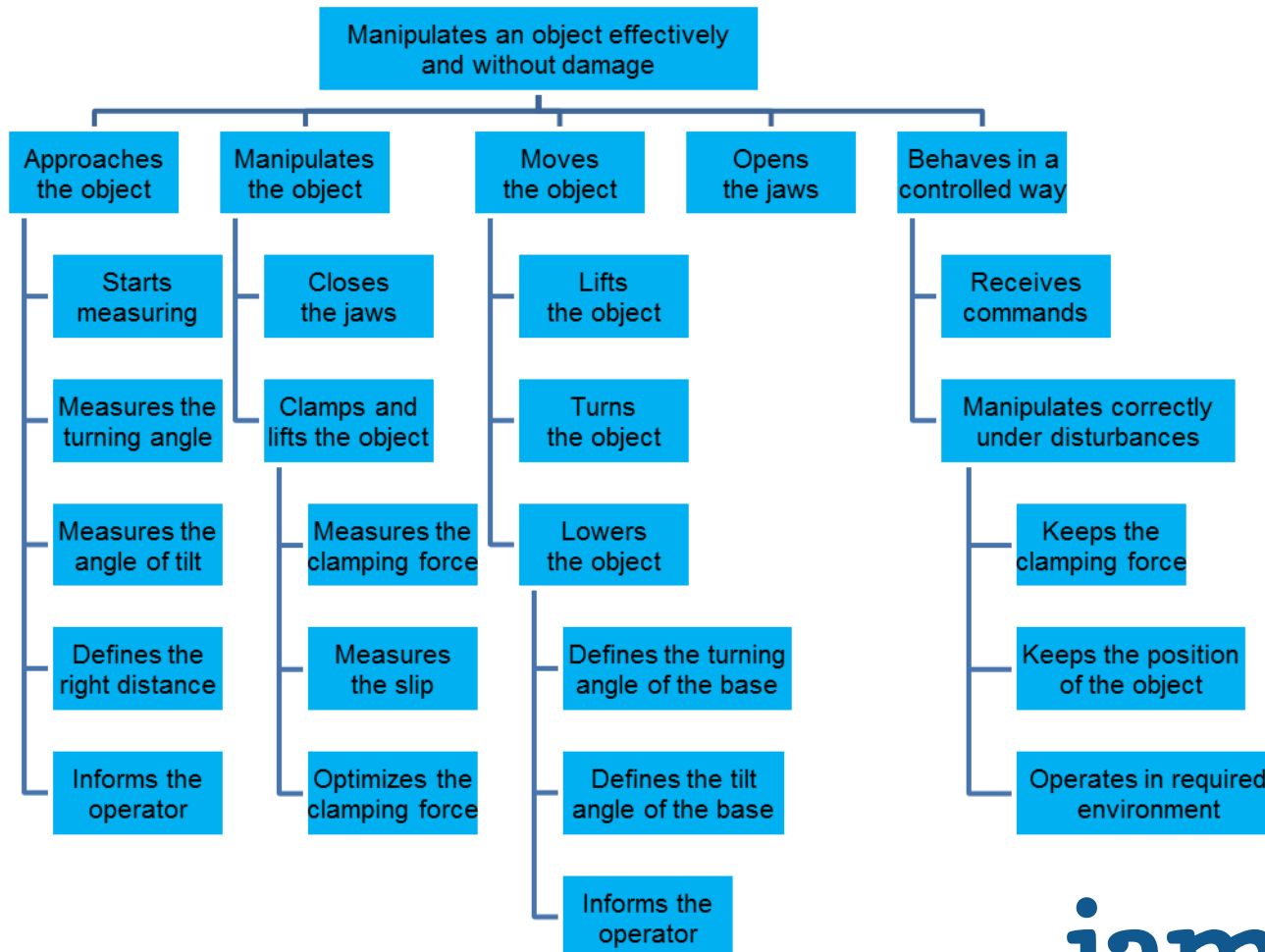
- result
 - function structure of the system (product)
 - documented solution principles of functions and justified evaluations
 - product concepts
 - final specification
 - marketing targets
 - proposal for production plan



Function structure



Function structure



Morphological chart

alternative

attributes (independent)

Anzahl der Profile (pro Rotorträger)	1	2	3		
Material	 Aluminium	 Stahl	 CFK	 GFK	
Profil	 Vierkant Rechteck	 I-Träger	 Rundrohr	 Flachmaterial	 Bosch Profile
Verbindungsart zur Mittelkonstruktion	Schrauben	Schweißen	Nieten	Kleben	
Motorbefestigung	Halterung geschraubt	Halterung geschweißt	Halterung genietet		
Befestigung Sensorik	In Motorhalterung integriert	seperate Vorrichtung	In Hohlprofil integriert		

the path shows one of many possible solution
best solution ???

Ideation methods

- brainstorming
- Gordon's brainstorming
- method 635
- synectics
- double team
- delphi-method
- bionics
- analogy method
- solution lists
- Idea Links
- Triz
- ...



Grading of ideas

- analytical comparison of alternatives
- group work → many viewpoints
- not necessary a consensus decision
- is based on properties which are important for customers
- formal decision methods should not be decision machines
- critical thinking → improving the weak points of best solutions
- optimism, encouragement for further development
- grading methods
 - grouping
 - common sense
 - selection tables
 - weighted grading scale



Selection table

SELECTION TABLE								
Solution variants	Selection criteria					Remarks	Decisions	
	(+) yes							(+) selected for further development
	(-) no							(-) rejected
	(?) more information needed						(?) more information neede	
	(!) requirement list must be checked						(!) requirement list must be checked	
	Criteria 1	Criteria 2	Criteria 3	...	Criteria N			
Solution 1								
Solution 2								
...								
Solution N								

Weighted grading scale

Selection Criteria	Weight	Concepts							
		A (reference)		DF		E		G+	
		Master Cylinder		Lever Stop		Swash Ring		Dial Screw+	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ease of handling	5%	3	0.15	3	0.15	4	0.2	4	0.2
Ease of use	15	3	0.45	4	0.6	4	0.6	3	0.45
Readability of settings	10	3	0.3	3	0.3	5	0.5	5	0.5
Dose metering accuracy	25	3	0.75	3	0.75	2	0.5	3	0.75
Durability	15	3	0.45	5	0.75	4	0.6	3	0.45
Ease of manufacture	20	3	0.6	3	0.6	2	0.4	2	0.4
Portability	10	3	0.3	3	0.3	3	0.3	3	0.3
Total Score		3.00		3.45		3.10		3.05	
Rank		4		1		2		3	
Continue?		No		Develop		No		No	

Weighted grading scale

Arvio Estimate	Points Pist.
Sopimaton Improper	0
Puutteellinen Insufficient	1
Vaikea ratkaisu Difficult	2
Hyväksyttävä Acceptable	3
Riittävä Sufficient	4
Tyydyttävä Satisfactory	5
Hyvä, hieman puutteellinen Almost good	6
Hyvä ratkaisu Good	7
Erittäin hyvä ratkaisu Very good	8
Yli tavoitteen More than focused	9
Ideaaliratkaisu Ideal	10

Arvio Estimate	Points Pist.
Ei hyväksyttävä Not acceptable	0
Juuri hyväksyttävä Just acceptable	1
Riittävä Sufficient	2
Hyvä Good	3
Erittäin hyvä Very good (ideaalinen) (ideal)	4



Paired comparison of grading criteria

ARVOSTELUKRITEERIEN PARIVERTAILU										Number	
ARVOSTELUKRITEERIT Grading criteria										Esiint.- kertoja	K
A											
B											
C											
D											
E											
F											
G											
H											
I											
										Summa Sum	

Vertaa kerrallaan kahta arvostelukriteeriä. Merkitse ruutuun tärkeämmän kriteerin kirjaintunnus.
 Laske vertailun jälkeen kirjainten esiintymiskerrat ja merkitse ne asianomaiselle riville.
 Painokerroin K saadaan jakamalla kunkin kirjaimen esiintymiskertojen määrä esiintymiskertojen summalla.
 Tarkista, että painokertoimien summa on likimäärin 1.



“Don’t go in yet – he’s making an important design decision.”

Embodiment design

- optimising and completing form designs
- checking for errors and cost effectiveness
- preparing the preliminary parts list and production documents
- process is strongly iterative
- many actions must be performed simultaneously



Embodiment design

- starting point
 - working structure or concept
- deliverables
 - overall layout design
 - general arrangement
 - spatial compatibility
 - preliminary form designs
 - component shapes and materials
 - production process
 - solutions for auxiliary functions
 - clear technical and economic evaluation



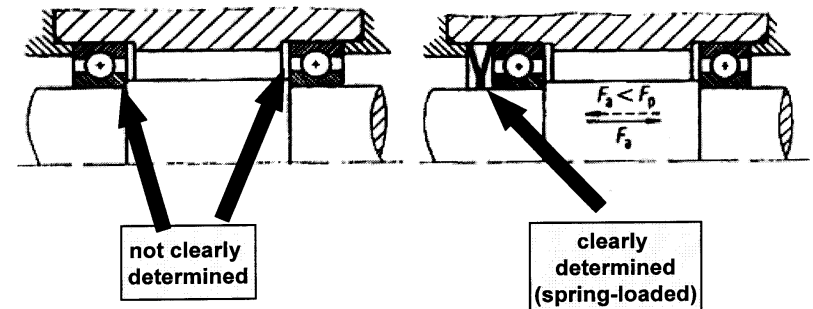
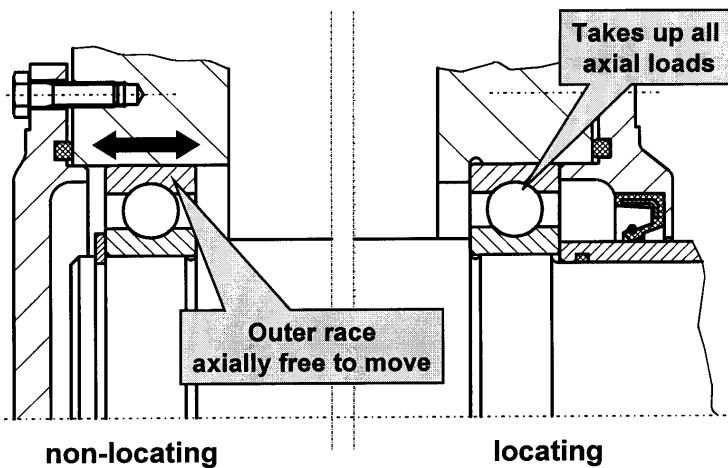
Embodiment design

- basic rules always apply and are fundamental to all principles and guidelines for embodiment design
- derived from the general objectives of product development:
 - fulfillment of technical function ..clarity
 - economic feasibility ..simplicity
 - individual and environmental safety ..safety



Embodiment design

- clarity



Embodiment design

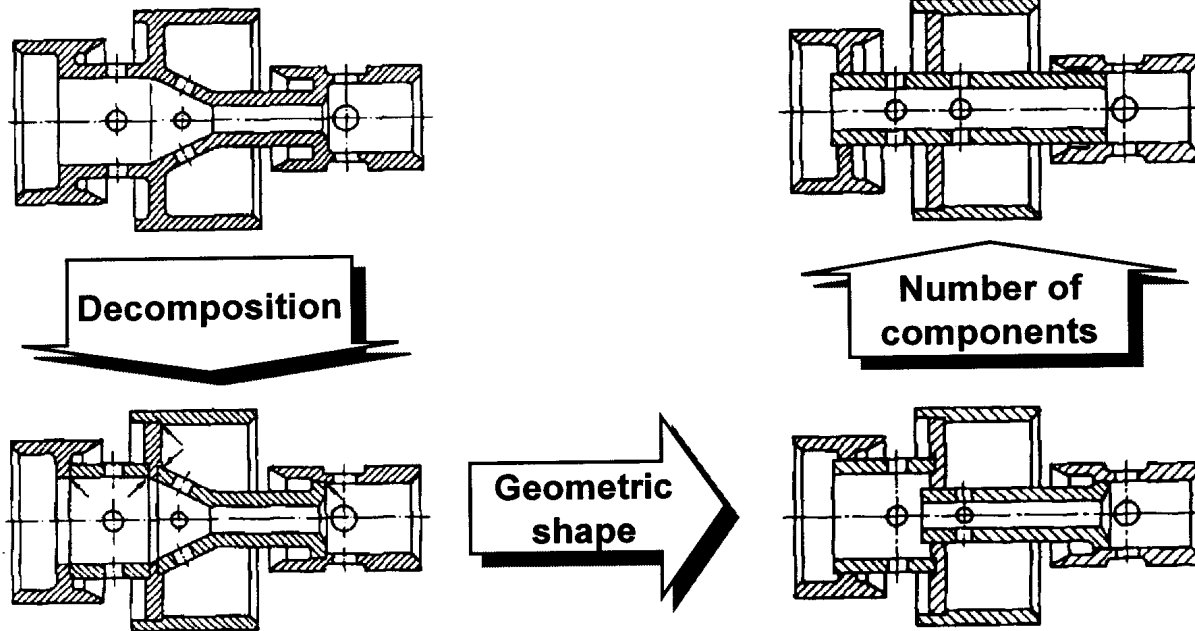
- simplicity
 - objectives: economic design, simple manufacture, assembly and maintenance
 - small number of components
 - simple geometric shape
 - transparent arrangement
 - function
 - minimum number of sub functions and clear and consistent combination
 - working principle
 - simple physical effects
 - only few parts needed for realization of this principle
 - few physical effects, identical types of energy



Embodiment design

- simplicity

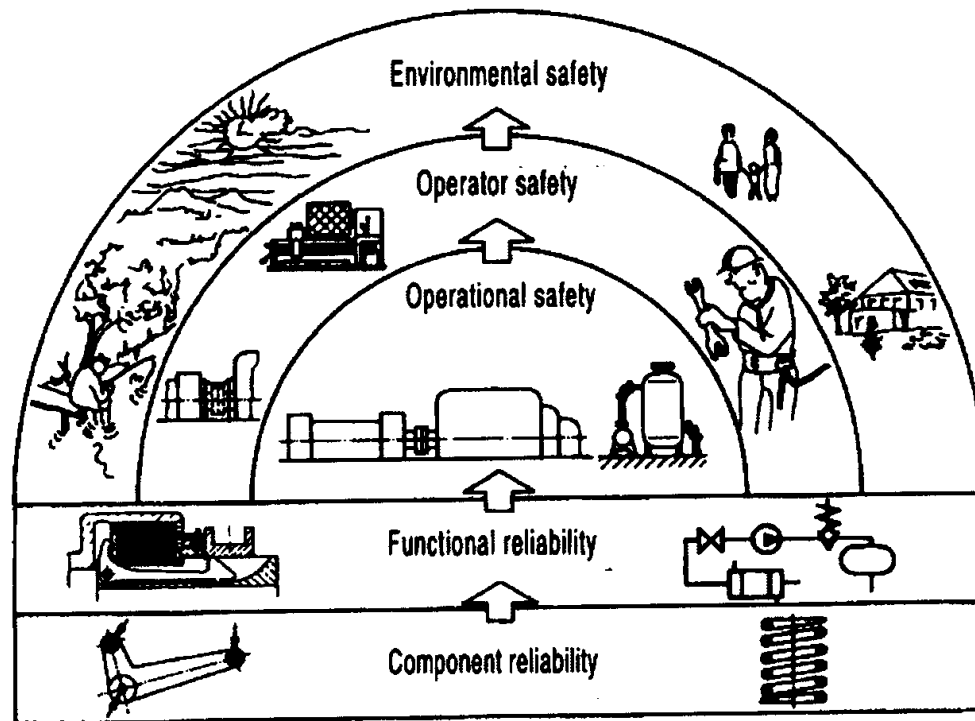
Example: Simplification of a control valve spindle



Embodiment design

- safety

Relationship between safety and reliability



Embodiment design

- check list for part and component selections
 - functional properties (performance, power, quality)
 - purchase cost
 - operation cost (energy, equipment)
 - reliability (operation reliability, maintainability)
 - safety (personal, environment)
 - ergonomics
 - compatibility with other system
 - part and component items



Detail design

- prepare preliminary parts list and production documents
- integrate overall layout drawings, assembly drawings and parts lists
- complete production documents including transport and operating instructions
- check all documents for standards, completeness and correctness



Detail design

- testing of a prototype
 - physical and functional connections
 - separate testing of control software by simulating error conditions
 - quantitative performance characteristics (capacity, power)
 - qualitative performance (operation, measuring and adjustment accuracy)
 - tolerance of environmental conditions (temperature, climate, noise, vibration)
 - voltage variations and electromagnetic disturbances



Detail design

- testing of a prototype
 - operation (with automatic control, according to user manual, with an abnormal manner)
 - checking of ergonomics
 - quality and maintainability checks
 - endurance and wear tests
 - installation checks
 - checking of personal and environment safety



Tekniset piirustukset/Technical Drawings

- Piirustusten sisältämä informaatio
 - Osien muoto ja mitat
 - Osien materiaalit
 - Käytettävät valmistusmenetelmät, toleranssit ja pinnanlaadut
 - Tuotteen kokoonpanoissa käytettävät menetelmät
- Tutkimuksen mukaan 60 % osista valmistetaan eri tavalla kuin piirustuksissa, koska
 - Piirustukset ovat epätäydelliset
 - Valmistusta ei voi tehdä tarkoitetulla tavalla
 - Piirustus ei ole yksikäsitteinen
 - Piirustuksen mukaisia osia ei voi asentaa

Tekniset piirustukset/Technical Drawings

- Suunnittelun eteneminen
 - Tuotteen lay-out –piirustus → osien piirustukset → kokoonpanopiirustukset
- Osapiirustukset (työpiirustukset)/Workshop drawings
 - Ohjeet osan valmistamiseen
 - Laadinta koneenpiirustusstandardien mukaan
 - Mitoitus
 - Toimintamitat (usein toleroidut)
 - Lujuusopilliset mitat
 - Valmistusmitat (esim. standardityökalujen perusteella)
 - Riippumattomat mitat



Tekniset piirustukset/Technical Drawings

- Kokoonpanopiirustukset/Assembly Drawings
 - Ohjeet osien ja komponenttien kiinnittämiseen toisiinsa
 - Kaikki tarvittavat osat ja komponentit
 - Kokoonpanojärjestys
 - Tuotteen pää- ja liitäntämitat
 - Työkalujen luoksepäästävyys huomiointi
 - Jako osakokoonpanoihin
 - Siirtoja ja kuljetuksia varten nosto- ja tartuntakohdat
 - Kuljetuksen aikaiset suojaukset



Tekniset piirustukset/Technical Drawings

- Mitoitusohjeita

- kaikki kappaleen kohdat mitoitettava yksiselitteisesti
- mitoitus ensisijaisesti koneistetuista pinnoista
- toleranssien summautuminen tulisi estää mitoituksella
- mitoituksen tulee mahdollisuuksien mukaan noudattaa kappaleen valmistusta
- mitta siihen, josta arvelee valmistajan sitä ensiksi etsivän
- mitoituksessa huomioitava myös tarkastus



Osaluettelo/Bill of Materials

- Liittyy kokoonpanopiirustukseen
- Tiedot myös tarvittavista raaka-aineista ja aihioista
- Osaluetteloa käytetään myös ostossa ja työnsuunnittelussa, joten oltava täydellinen (kuten piirustustenkin)
- Hierarkkinen rakenne (rakennepuu)

