Industrial Design Engineering of Consumer Goods from a business perspective

How to respond to current challenges

TCME 2006, Industrial tutorial presentation

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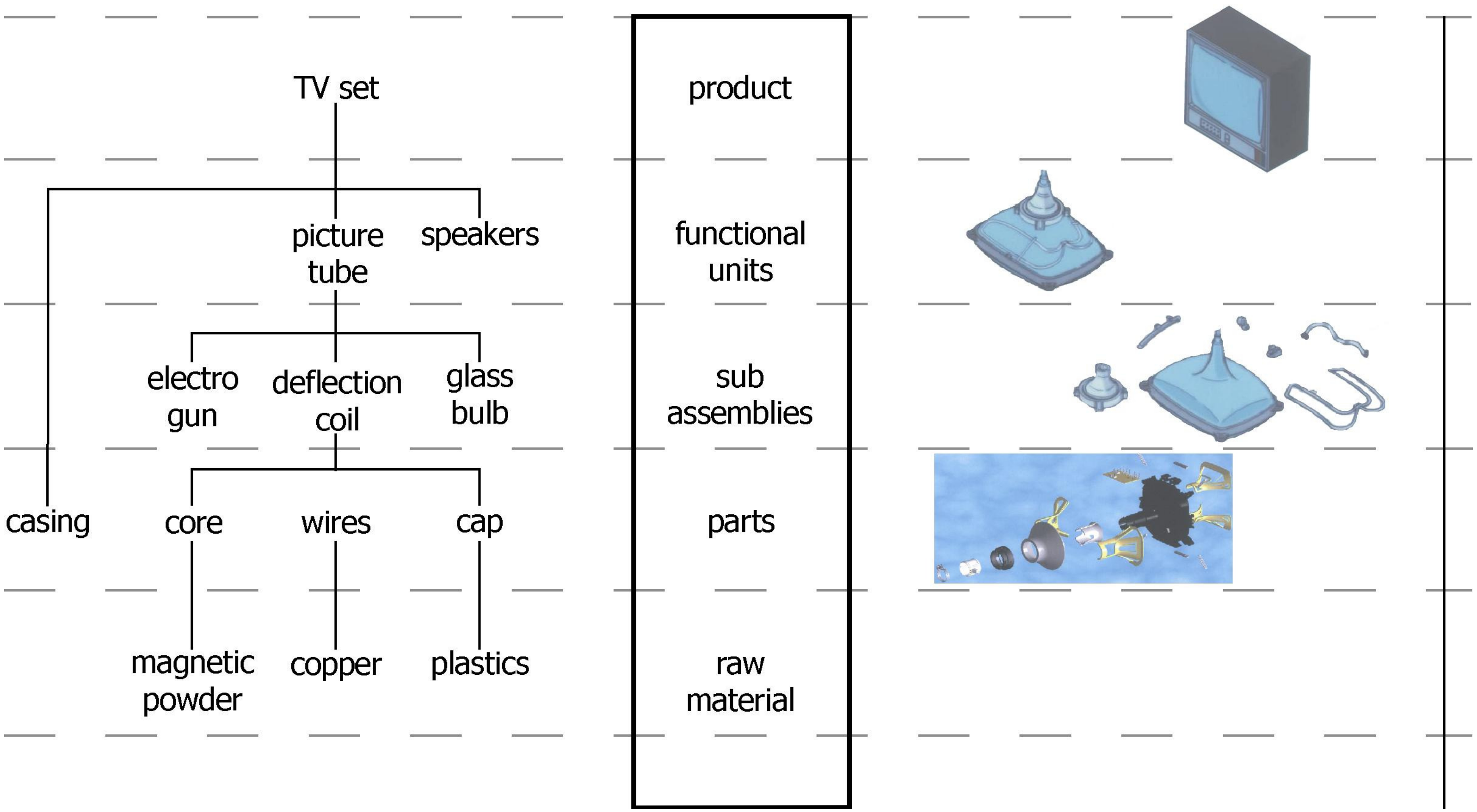
Delft University of Technology

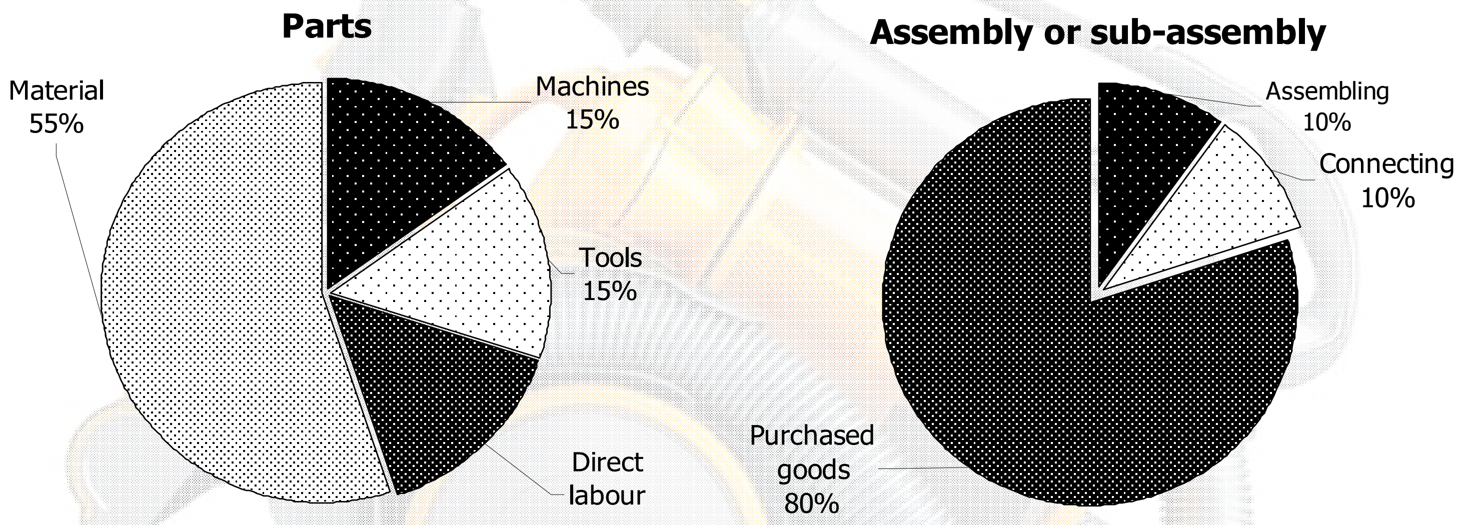
Introduction

- **What are consumer goods**
  - products that are used by us
  - TV, DVD, domestic appliances, bicycles, cameras
  - large series (10.000/y) or mass production
  - medium – high tech
  - style is important
  - branding is essential in communication
  - strong international competition
  - growth/mature market

Introduction
Structure of consumer goods



Introduction
Costprice of consumer goods



- type of product ➔ labor content ➔ technology push

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Introduction

- **Personal experience**
  - 35 years of industrial experience in innovation and production
  - two years at the faculty of Industrial Design Engineering of Delft University of Technology

- **University has lots to offer**
  - detail knowledge
  - capabilities and capacity
  - enthusiasm

- **Gap**
  - knowledge of the design process in industrial practice
  - which items are important and why

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Introduction

- We combined industrial issues and university opportunities for consumer goods
- Share our strategic choices with you

- **Agenda:**
  - Design Engineering of consumer goods
  - What kind of industrial business are we in
  - Trends in the consumer goods industry
  - How does the industrial sector react to these trends
  - What has to be developed in our profession to anticipate on future trends
  - Knowledge, means and methods to overcome the gaps

Design Engineering of consumer goods

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Design

Industrial Design ↗↘ ↖↙ interactive process

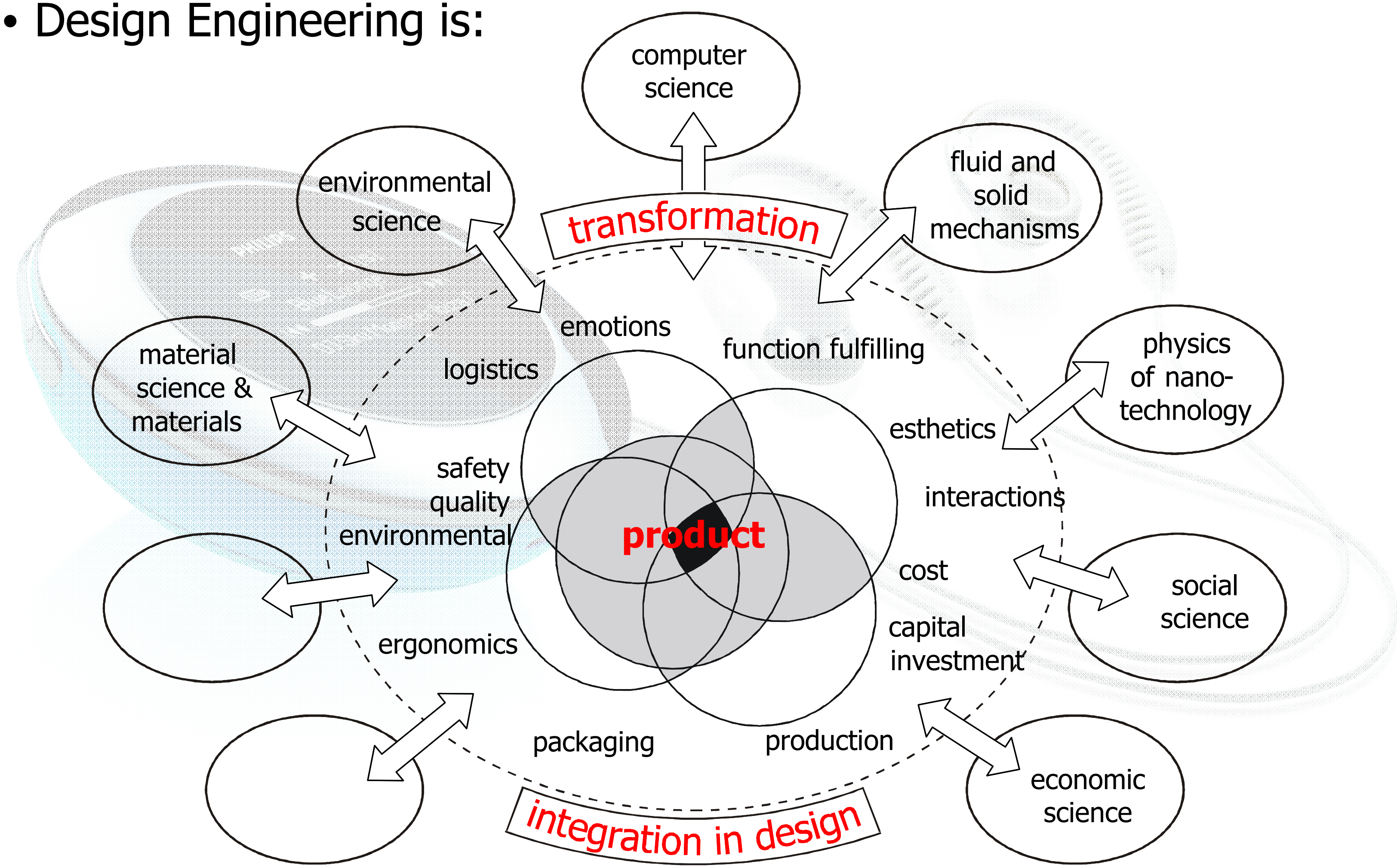
Design Engineering

- Cost of development 4-8% of turnover/year

- Design (5%)
  - main outlines, global specifications, composition (shape), customer/product interaction (fuzzy front end)

- Design Engineering (95%)
  - fix the design in all his details
    - design requirements, function, reliable, safe, quality, environment
    - production, production means/capital investment
    - financial requirements
  - developing parts
  - transfer to production
  - redesign (half of total development cost 2-4%/year)

- Design Engineering is:



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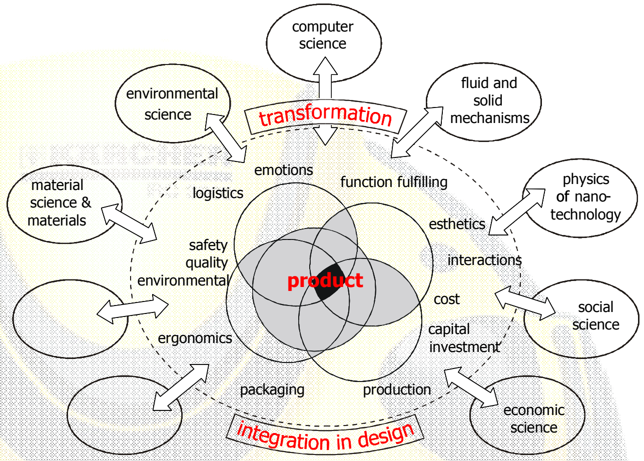
• Design Engineering is:



- building up understanding of all relevant aspects
- use knowledge of specialists and transform this into usable knowledge for product development
- developing possible solutions
- make choices
- phased process
- understand mathematics, physics, thermodynamics, economics, business, etc.

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- Design Engineering is not:
  - a flow of precise scientific reasoning in a narrow, well defined area

- Culture of the university

- Design Engineering is:
  - not for ‘single band’ but more for ‘wide band’ technicians
  - iterative process of making choices
  - end result depends on the creativity and virtuosity of the designer

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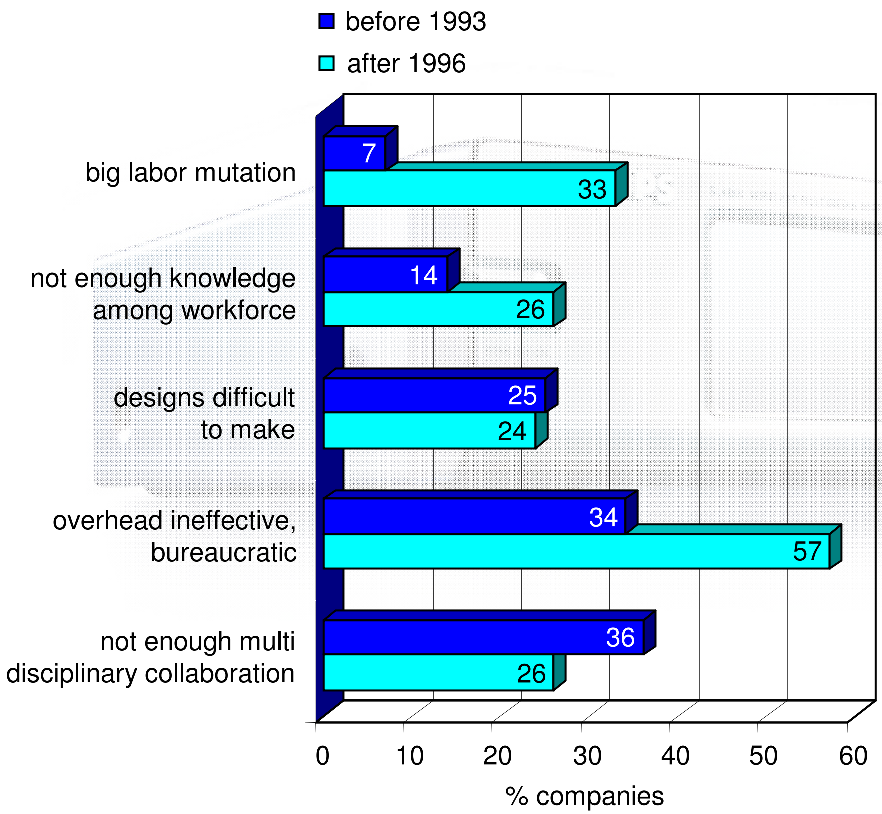

- Specific for Design Engineering of end-consumer goods is:
  - a physical process is used to fulfill the basic function
  - minimize use of material
  - production

- Success of development is depends on the quality of the entire chain including production

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The market

→ time

market requirements	1960	1970	1980	1990	2000	required performance industry
costs						efficiency
+ quality						quality
+ assortment and delivery time						flexibility and speed
+ uniqueness (mass customization)						innovation = development with time pressure
+ total solutions						multi disciplinary collaboration

- Because of more pressure from competition, companies extend the competition area
- You cannot fight on uniqueness when you don't have control over your Cost, Quality and Flexibility
- When you are equal to the competition you fight on costs again

To compete you need a large assortment, sharp priced, modern, unique, attractive products of good quality with the latest technological possibilities

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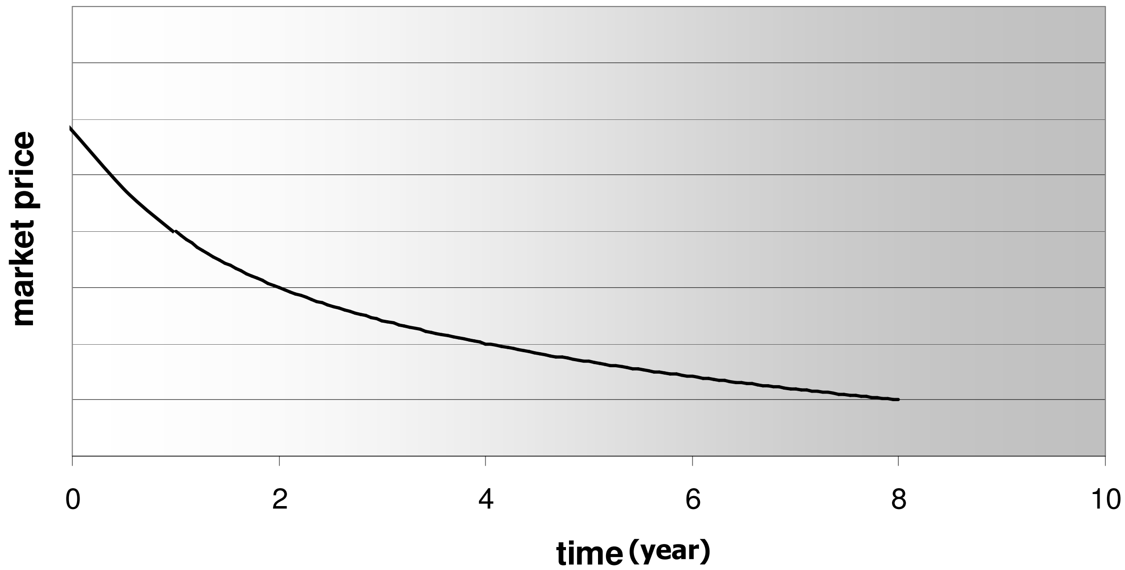
The market

Price erosion of consumer goods (mid- and high tech)



Price erosion:

~50% products ≤4%/year

~45% products 4-8%/year

- Price is and stays a dominant factor
- New types, new applications can delay the erosion
- Cost reduction by production/design improvement (aftercare ←→ learning curve)

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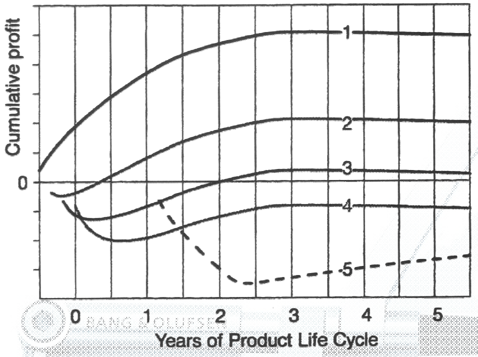
The market
Time to market

#Profit development



8 months later

Combination of:
- Learning curve
- Market price erosion
- Market introduction
- Relation customer – supplier (contracts)

#Lifecycle products (years)

	1990	2000
- TV	1-4	1-2
- Audio	< 1	<1
- Video cam.	1-2	0,5-1
- Pers. comp.	2-3	1
- Mobile phone	1-1,5	0,5

source: Philips

#Ever faster cloning (≤ 0,5-1 year)

Time to market is essential for making profit.

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The industrial company

Company objectives

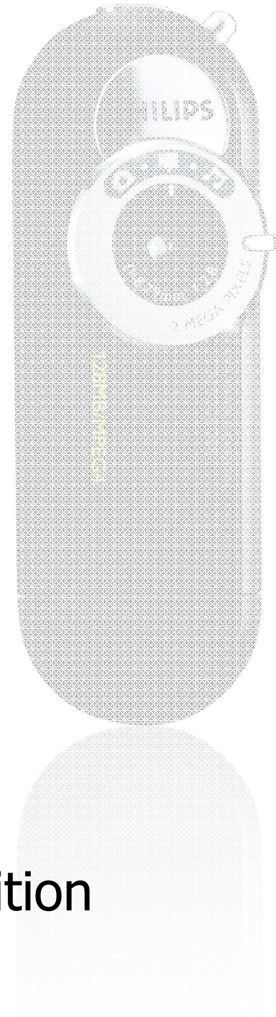
- Making money
- As soon as possible
- Minimum risk and effort
- Often in continuity

Condition of existence of a company

- Meaningful for stakeholders
  - customers
  - employees
  - shareholders
  - government
  - suppliers
- Efficient
- Focused on continuity

Money is the main driver. Tendency to move production **and innovation** to low wage countries.

The industrial company



Company cultures

'Anglo-Saxon'

- Short term profit
- Maximize profitability
- Shareholders
- 'Big jump forwards' improvement behavior

'Asian and Rheinland'

- Dominance in market position/share
- Success via products properties
- Technological leadership ➔ leading market position
- 'Step by step' improvement behavior

The industrial company
Cost – performance of a company

- **Cost model**

Intake cost
•Direct material
•Indirect material
•Energy
•Services

→

Invested capital
•Buildings
•Machines
•Inventory
•Work in progress (wip)

Exploitation costs
•Investments
•Insurance
•Depreciation

↑

Labor costs
•Direct
•indirect

⇒

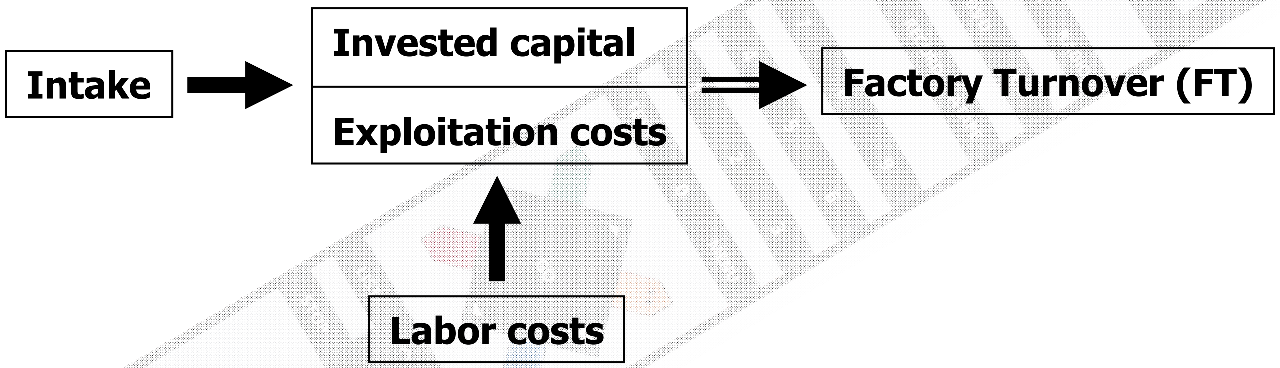
Factory turnover

Number of products
*
Factory standard price

- **Buildup of labor force**
  - Creative part (product / process development) ≈ 10%
  - Indirect/direct costs ≈ 0,8/1

The industrial company
Making money

- **Cost model**



- **Practical data:**

  # ROI 10-20% (Return On Investment = profit / capital inv.)

  # Turnover speed of capital 0,5 – 5 (total sales / capital inv.)

  # Added value to the product 15-60% ((labor + exploitation costs)/ FT value)

  ⇓

  Type of industry & performance

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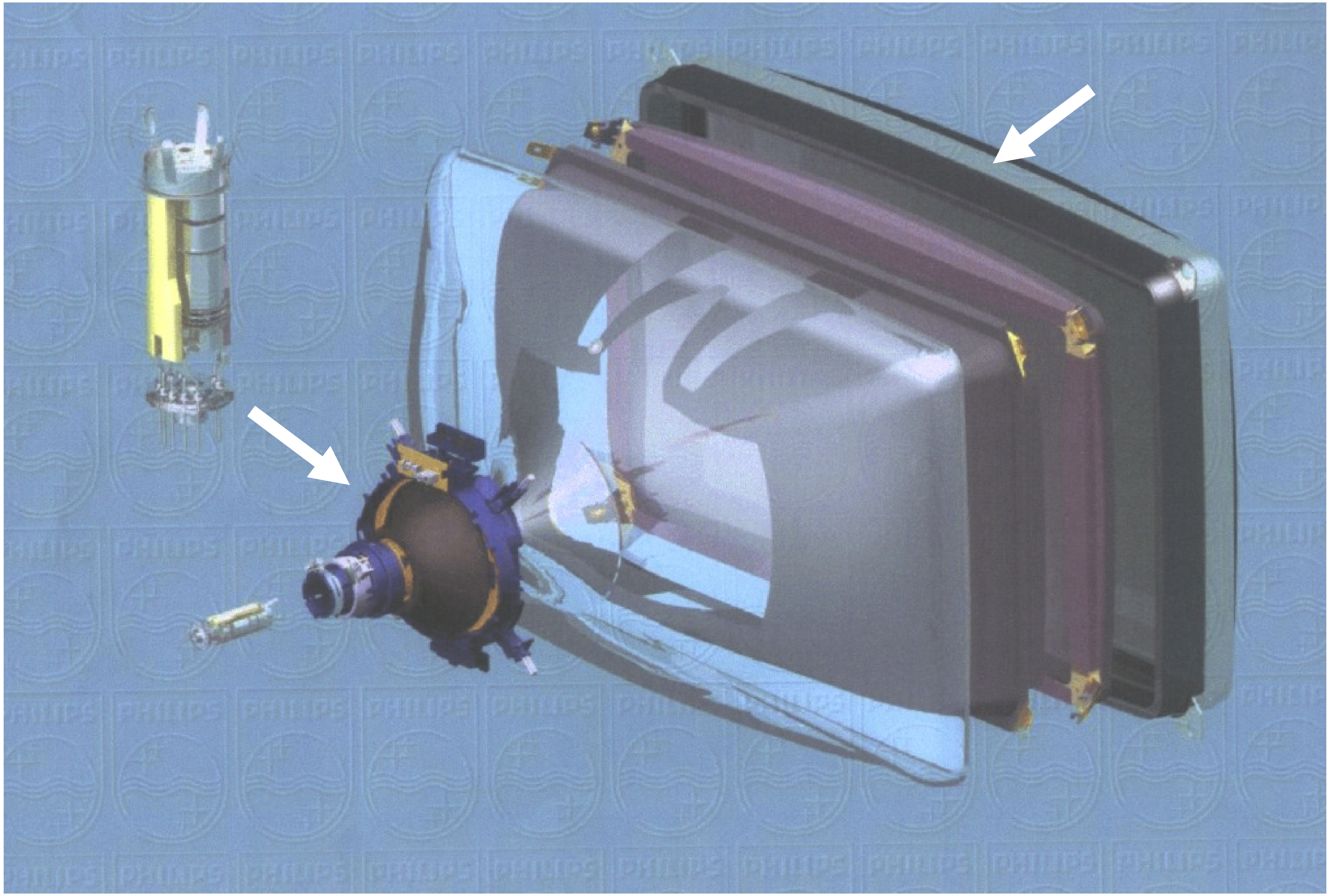

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Amounts in NLG x 10^6

Costmodel Glass factories

Intake

Direct Material	208
Energy	56
Miscellaneous	52
	316

48%

Invested capital
Replacement value

Buildings	195
Equipment/utilities	703
Stocks	99
Total	997

FSP Value 658

100%

Exploitation costs 95

15%

Labour costs

Directs	132
Indirects	115
Total	247

37%

Added Value	52%
Material Value	32%
Vcapital	0.66

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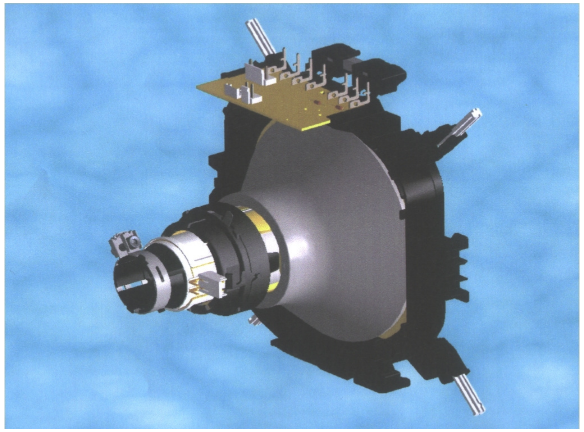
Costmodel DU's

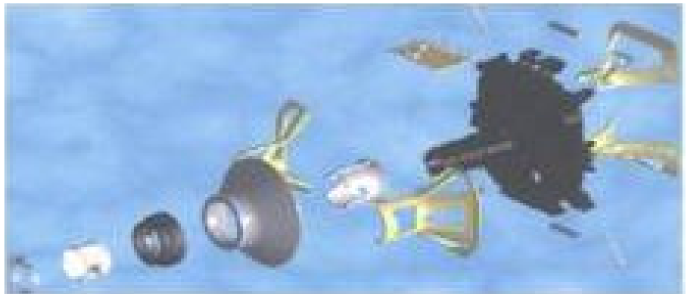
Amounts in NLG x 10^6

Intake

Direct Material	236
Energy	4
Miscellaneous	8
	248

74%





Invested capital
Replacement value

Buildings	25
Equipment/utilities	128
Stocks	17
Total	170

Exploitation costs 26

8%

FSP Value 336

100%

Labour costs

Directs	35
Indirects	27
Total	62

18%

Added Value	26%
Material Value	70%
Vcapital	1.98

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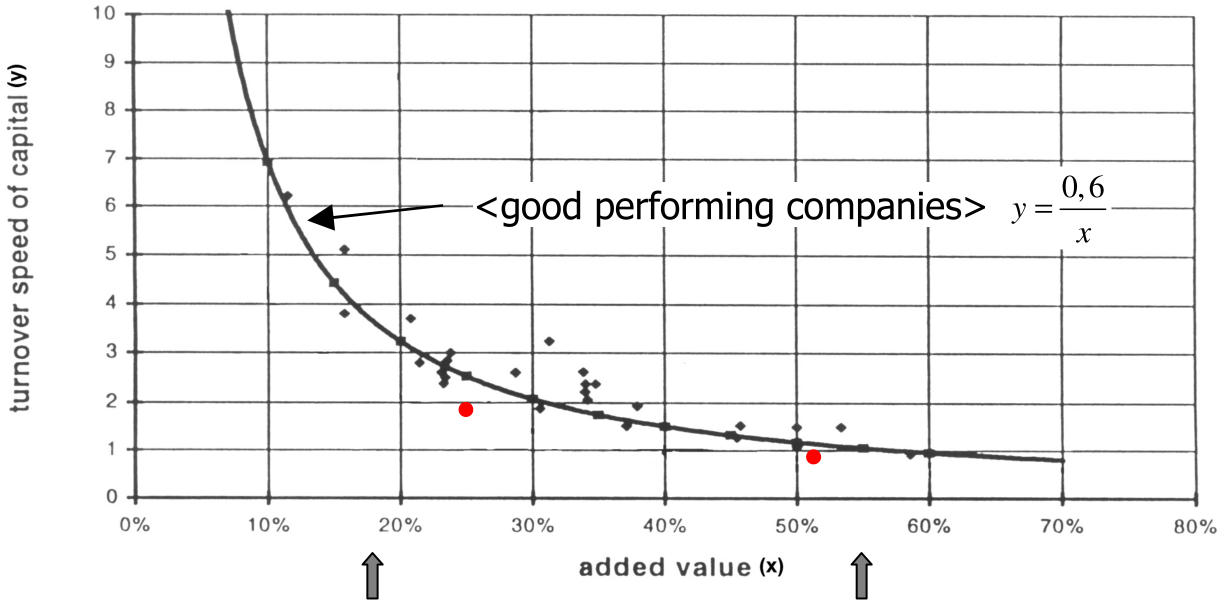
The industrial company
Type and performance



Final product
- assembly industry
  - diversity management
  - obsolete stocks
  - purchasing

Parts
- process industry
  - capital use
  - yield (process control)
  - material consumption

Huge difference in design aspects.

The industrial company

Characteristics & relative importance

	Turnover speed of capital	Turnover per man	Ratio Indirects / Directs	Capital use per man	Added value	Diversity in products	Diversity in technologies	Product lifecycle	Major problem areas: Process control complexity	Logist. Control complexity	Effective use of capital invested
• Raw material refinements (glass, IC foundries, ...) • Single component manufacturing (resistors, bolts, nuts) • Subassemblies • Functional units (pic.tub., shaverheads, PCB's, motors) • Final set assemblies (TV's, shavers, heaters, testers)	↓	↓	↓	↑	↑	↓	↑	↑	↑	↓	↑

→ Increase importance in direction of the arrow

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The industrial company
Industrial data product cost

	added value %	labor %	capital %	misc. %	material %
parts	± 60	30	15	15	35-55
functional units	± 40	20	10	10	50-60
final product assembly	± 20	10	2	8	70-80
integral cost final product	50-60	25-35			40-50

- Trend: less assembly and labor content
- Indirect / direct labor cost ratio: 0,8/1
- 80% products less than 0,5 hours work content
- Move ratio < 10%
- Integral cost price of final product ≈ 2 x sum of material cost

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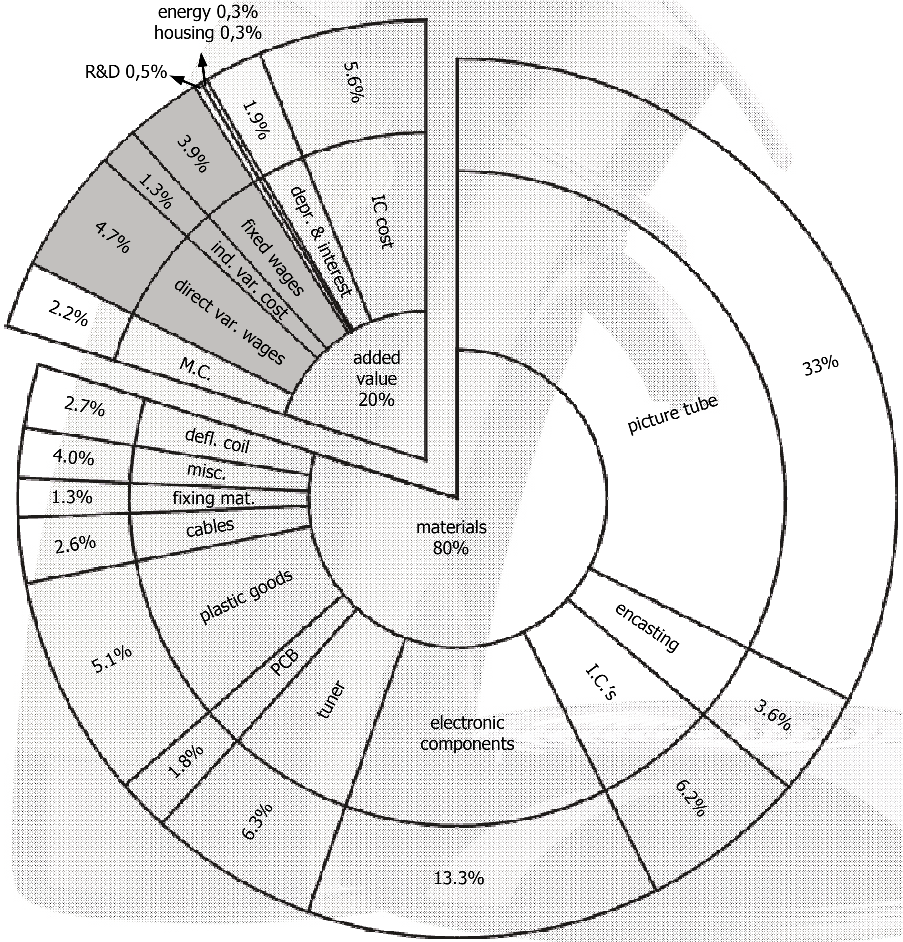
The industrial company
Buildup of cost price of a TV set



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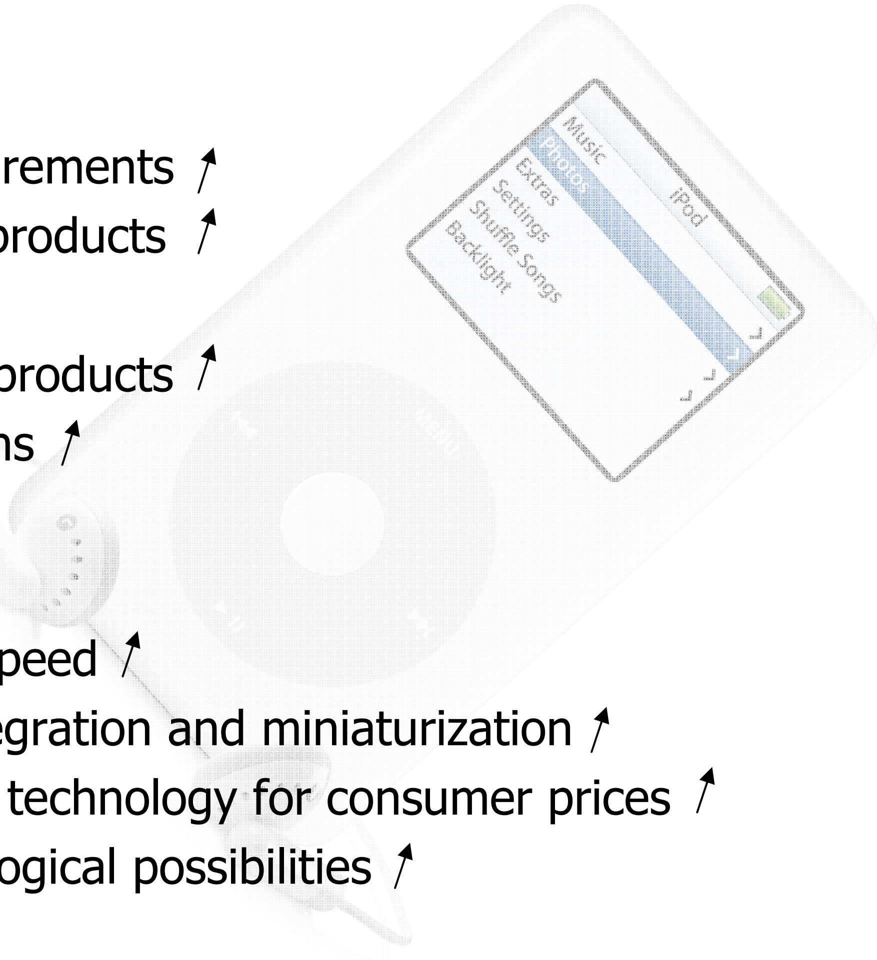
Trends in consumer goods industry

- Market
  - costs ↙
  - quality requirements ↗
  - diversity in products ↗
  - lifecycle ↙
  - customized products ↗
  - total solutions ↗
  - cloning ↗
- Technology
  - innovation speed ↗
  - function integration and miniaturization ↗
  - professional technology for consumer prices ↗
  - new technological possibilities ↗



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- Industry
  - turnover speed of money ↑
  - global horizontal specialism ↑
  - labor costs and education ↑
- Government
  - environmental requirements ↑
  - exchange rate ↕
- Society
  - spending power in regions ↕

And: shareholders claim short term profits

Reaction from the industrial sector

- **Simultaneous fulfilling next demands:**
  - Efficiency (cost)
  - Quality
  - Flexibility (assortment, delivery time)
  - Speed (time to market)
  - Innovation (development under time pressure)
  - Total systems (multi disciplinary cooperation)

- **Taking into account:**
  - Company objectives
  - Type of industry

Contradictary requirements hard to match

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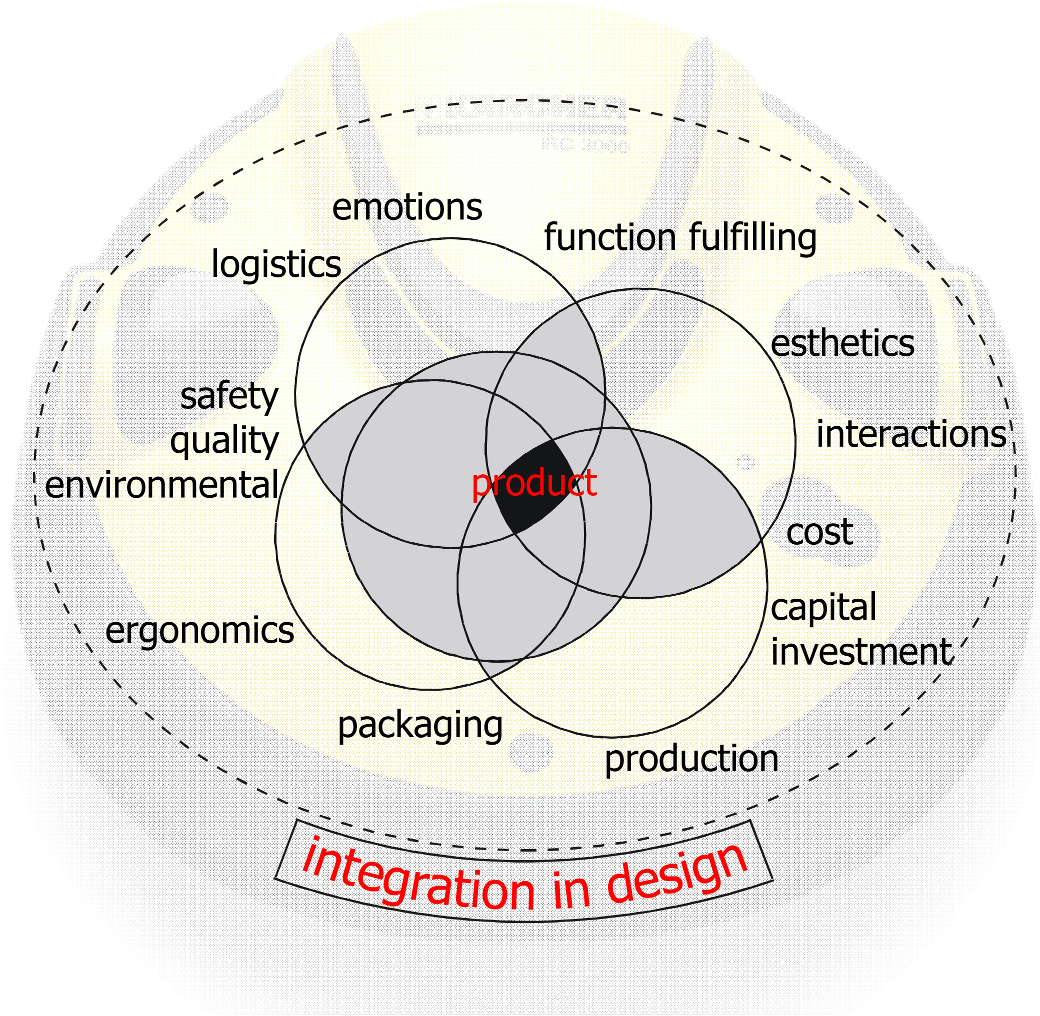
- **By:**
  - **an integrated approach (no sub optimalization)**
  - **reduction of complexity**
  - **use of advanced technologies (only when profitable)**
  - **design with quantitative understanding of working principle and critical design elements (improve development process)**
  - **continue integration of functions and miniaturization of parts**
  - flexible and innovative organization structure
  - well justified socio-technical choices (people work)

Integrated approach



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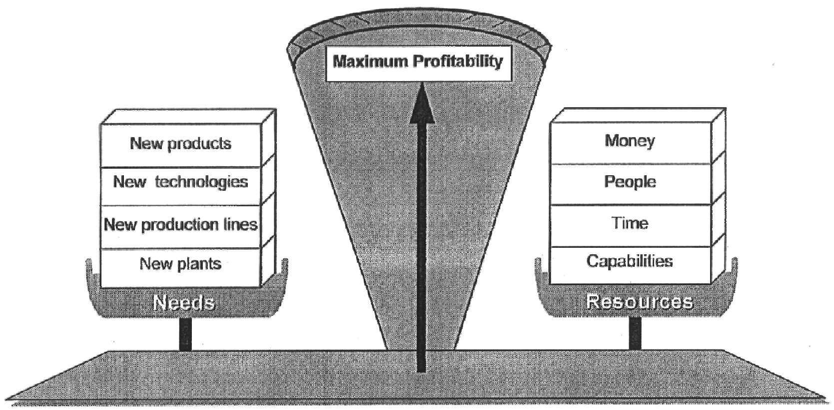
Integrated approach

- To agree on a product portfolio plan including technology and research projects is a

Multifunctional business process

- Considering: - Business objectives
  - Entire industrial chain



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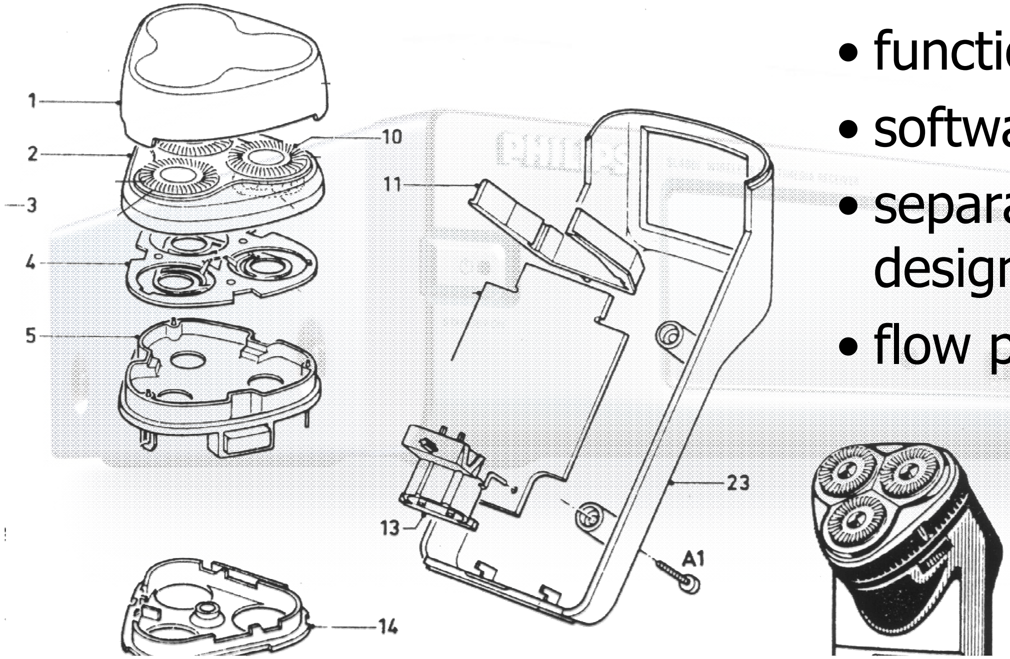
Reducing complexity of products



- modular structure
- functional units
- software, intelligence
- separate technical inside from design appearance
- flow production

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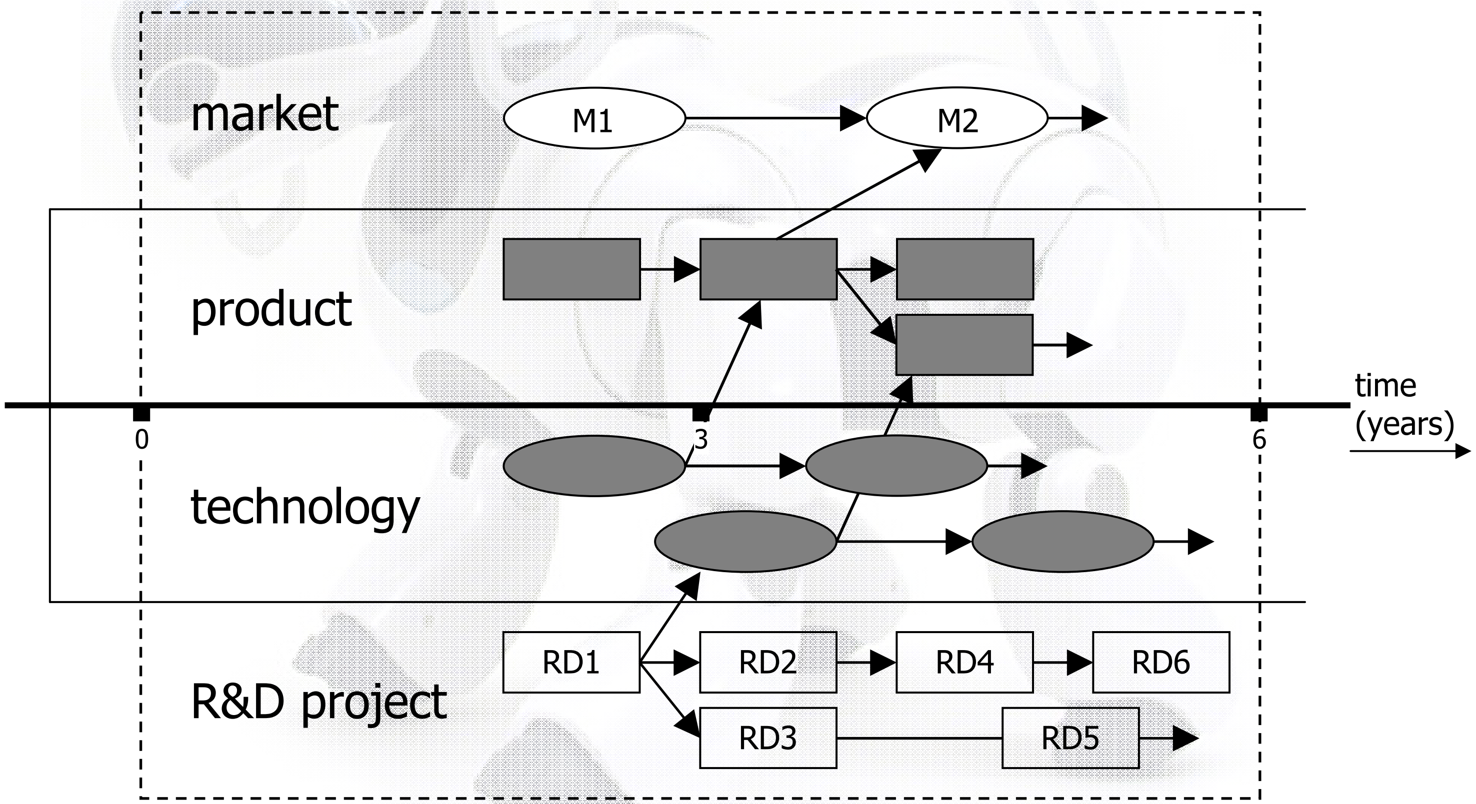
Use of advanced technologies and technology on stock



Linked marketing-, product-, components,- industrial-, technology-, research- plans.

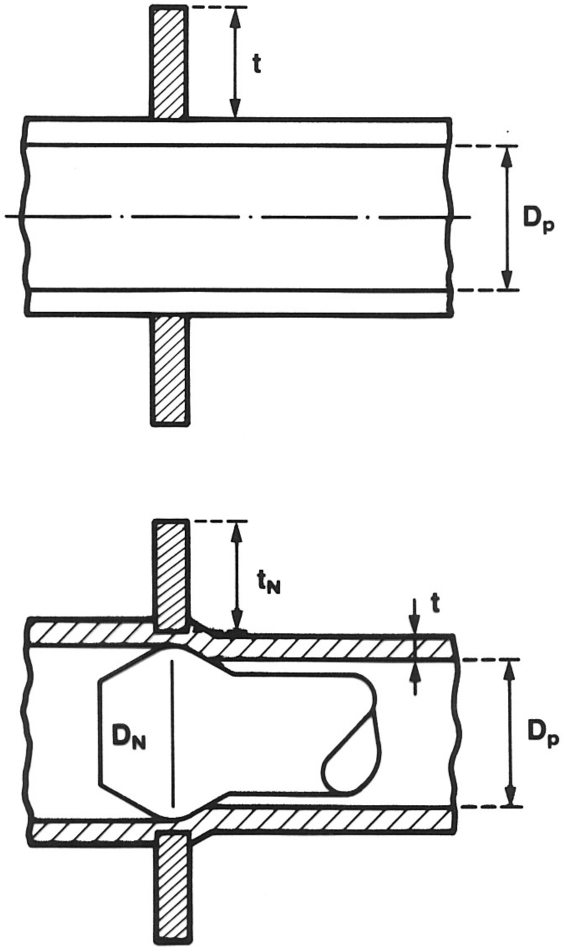
Improve product development process

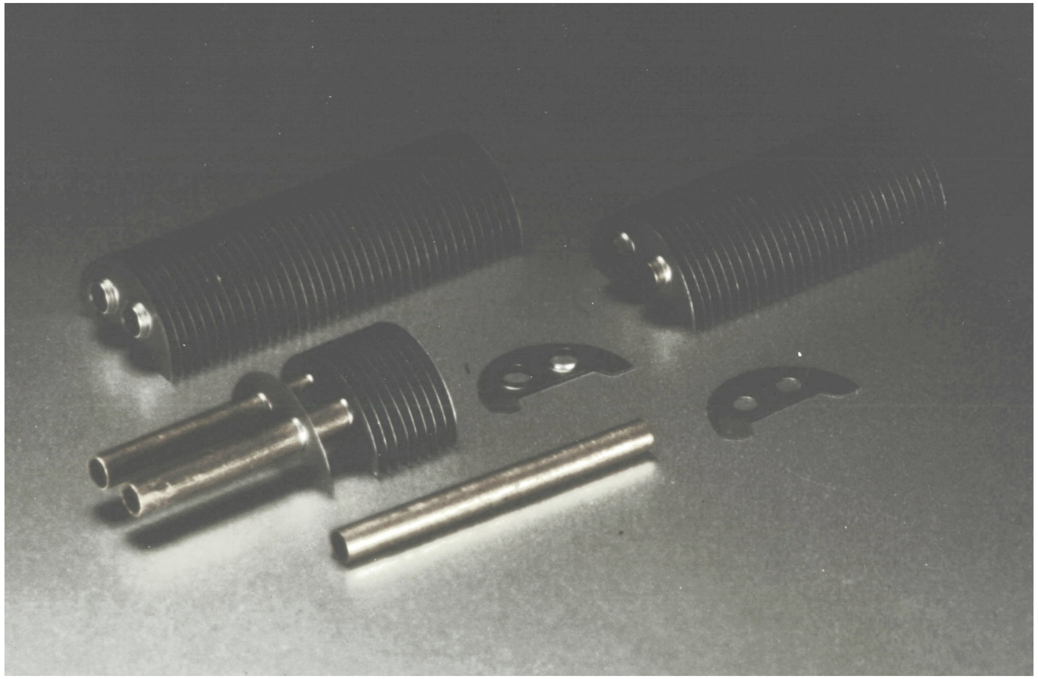
- First time right
  we design a product and are amazed of what is coming out!!!
  - **Essential**: Understand the **process** with which the **product** fulfills its **function**
    - Coffee making process (physical, chemical, thermal)
    - Laser optics
    - Hair cutting, catching hair a. o.

    Understanding the behavior of **critical construction elements**
  - **Important**: Test the functioning as early as possible. Also have a **quantitative understanding**.
    Which parameters are responsible for the functioning of the product.
    What is the relation between the parameters. (➔ reliability, parts per million)
  - **Prototype**: Check the prediction of the behavior.

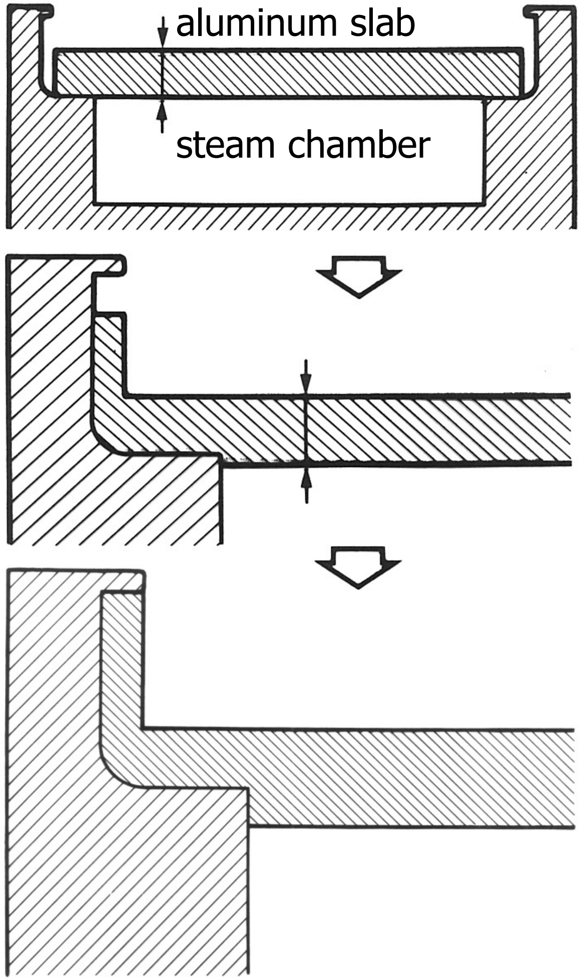
Predictable behavior ➔ first time right ➔ shorten time to market

Fixation of lamellas of lady shaver.





Sealing steam chamber of steam iron



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What has to be developed in our profession to anticipate on future trends?

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Extension of knowledge

- Product functioning
  - 50% of all product development fails due to not having control over the process that fulfills the primary function of a product (ex.: making coffee, shaving skin, display picture)
  - transferable and quantified knowledge
  - methods and tools to gain knowledge in a quick and easy way
- Production
  - 60% of the developed products have a delay due to ‘running-in’ problems. 25% needs a redesign
  - more and more production at a distance
  - knowledge, means and methods to integrate production possibilities in an early phase of the design

Extension of knowledge

- Introduction of technological inventions
  - time from invention to successful introduction in a product is 20 ≈ 30 years
  - knowledge, tools and methods to reduce the time drastically or to be able to decide in an early stage of development to stop or to continue

- Bridging the gap between the ‘soft’ and ‘hard’ discipline of industrial design engineering
  - how can we predict the success of a ‘Senseo’ coffee maker before and not after the introduction
  - knowledge to translate the user appearance and user experience of a product in transferable and quantified knowledge for a technical designer: make subjective items concrete

Knowledge, mean and methods to overcome the gaps

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Technics to solve problems:

	Knowledge gained	Experience gained	Duration (ratio)
(computer-) experiments	- none	+++	1
Multiple correlations	+ small increase	++	1000
Dimensional analysis	**++ increase much**	**++**	**10**
Theoretical analysis	+++ increase a lot	-	2000

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Case: Senseo

Strength

- Fast
- Clean
- Dish washer
- Crema layer
- Different blends
- Simple to use

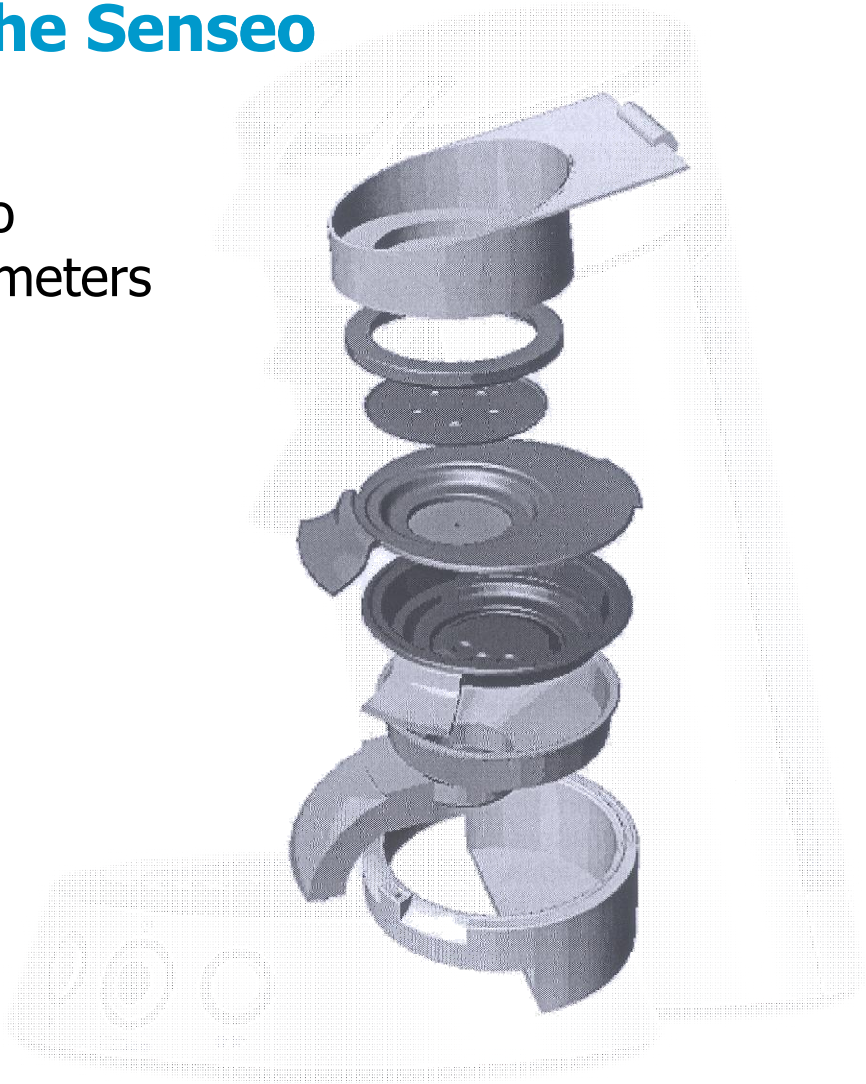
Weaknesses

- Only pods*
- 1 or 2 cups
- Closing the lid
- Noise
- Vibrations
- Purchase price

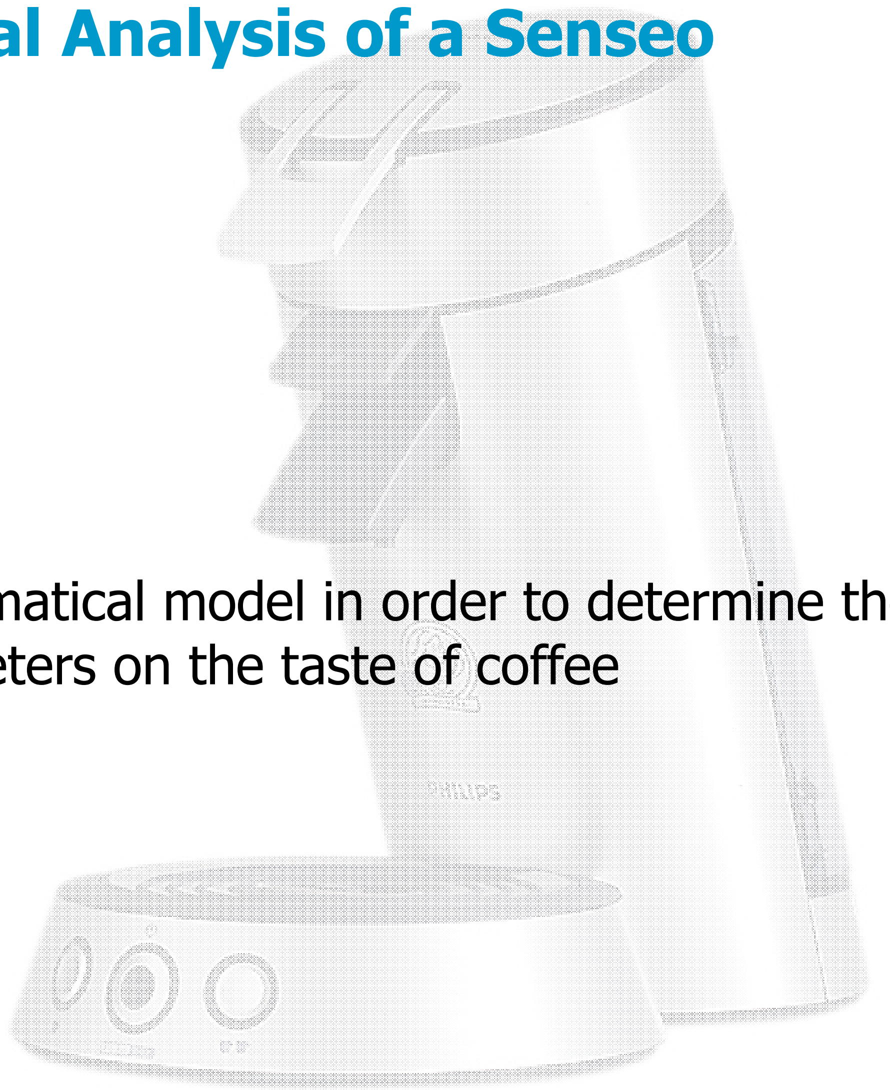
*in Dutch: pads

Design of the Senseo

Pay attention to
important parameters



Dimensional Analysis of a Senseo

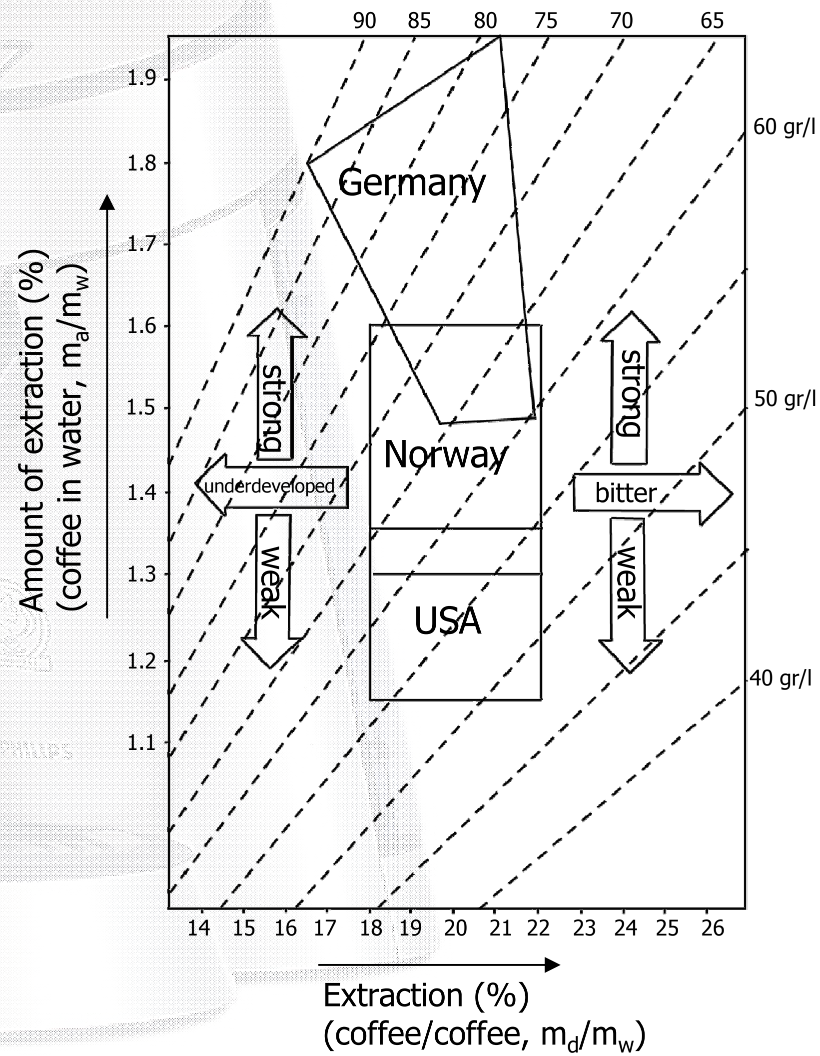


- Taste
- Crema
- Experience

Make a mathematical model in order to determine the influences of various parameters on the taste of coffee

The taste of coffee

- Differences between countries
- Lockhart chart



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Parameters, used in taste analysis

The mechanism behind taste

Amount of particles dissolved in the coffee	m_d	kg	M
Amount of coffee	m_m	kg	M
Temperature of water	T_w	K	θ
Pressure	p	N/m^2	$ML^{-1}T^{-2}$
Diameter pod holder nozzle	d_p	m	L
Diameter lid nozzles	d_s	m	L
Width pods	l_m	m	L
Durability Crema	t_c	s	T
Volume grain of coffee	V_{md}	m^3	L^3
Permeability coffee pods	A_f	m^2	L^2
Diameter of the coffee cake	d_m	m	L
Amount of water	m_w	kg	M
Heat transfer coefficient coffee	κ	W/m^2K	$MT^{-3}\theta^{-1}$
Thermal diffusivity coffee	a	m^2/s	L^2T^{-1}

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The simplified dimensional matrix

- This leaves a, m_w, d_m, t_c, p, T_w and κ:

$$
\begin{array}{c|ccccccc|l}
 & \kappa & a & m_w & d_m & t_c & p & T_w & \\
\hline
M & 1 & 0 & 1 & 0 & 0 & 1 & 0 & \Rightarrow \text{M(ass)} \\
L & 0 & 2 & 0 & 1 & 0 & -1 & 0 & \Rightarrow \text{L(ength)} \\
T & -3 & -1 & 0 & 0 & 1 & -2 & 0 & \Rightarrow \text{T(ime)} \\
\theta & -1 & 0 & 0 & 0 & 0 & 0 & 1 & \Rightarrow \theta\text{(degree)}
\end{array}
$$

Dimensionless products

$$\Pi_1 = \frac{m_d}{m_w} \qquad \Pi_2 = \frac{V_{md}}{d_m^3} \qquad \Pi_3 = \frac{d_p}{d_m}$$

$$\Pi_4 = \frac{A_f}{d_m^2} \qquad \Pi_5 = \frac{d_s}{d_m} \qquad \Pi_6 = \frac{l_m}{d_m}$$

$$\Pi_7 = \frac{m_m}{m_w}$$

$$\Pi_{10} = \frac{a \cdot t_c}{d_m^2} \qquad \Pi_8 = \frac{\kappa \cdot d_m^6 \cdot T_w}{a^3 \cdot m_w} \qquad \Pi_9 = \frac{d_m^5 \cdot p}{a^2 \cdot m_w}$$

Hypothesis:

$$\Pi_1 = C \cdot \Pi_2^{k_1} \cdot \Pi_3^{k_2} \cdot \Pi_4^{k_3} \cdot \Pi_5^{k_4} \cdot \Pi_6^{k_5} \cdot \Pi_7^{k_6} \cdot \Pi_8^{k_7} \cdot \Pi_9^{k_8} \cdot \Pi_{10}^{k_9}$$

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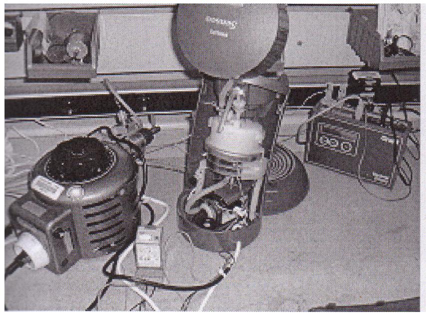
The experiments

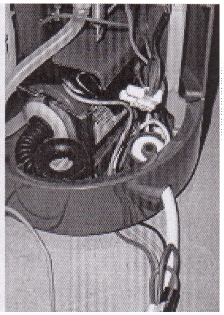
- Preparations
- Example:

$$\left[\frac{m_d}{m_w}\right] = C_4 \cdot \left[\frac{d_s}{d_m}\right]^{k_4}$$

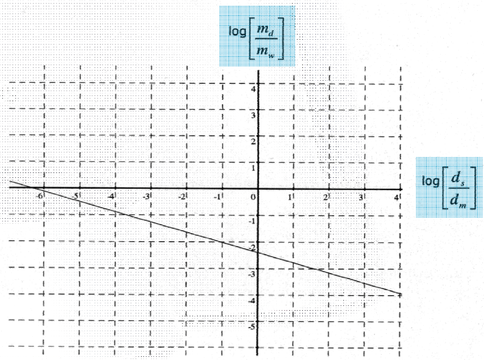
$$\log\left[\frac{m_d}{m_w}\right] = \log C_4 + k_4 \cdot \log\left[\frac{d_s}{d_m}\right]$$

$\log\left[\frac{m_d}{m_w}\right]$	$\log\left[\frac{d_s}{d_m}\right]$
-1,939	-1,234
-1,959	-1,176
-1,981	-1,124





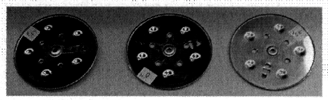
Lineaire regressielijn (y= a+bx):
a= -2,409
b= -0,381
correlatiecoëfficiënt (r)= 0,997



<u>Uitkomst:</u>

d_s	m_d	m_w
Ø $3{,}5 \cdot 10^{-3}$ m	$1{,}536 \cdot 10^{-3}$ kg vaste deeltjes	$133{,}5 \cdot 10^{-3}$ kg koffie (Exp5.2)
Ø $4{,}0 \cdot 10^{-3}$ m	$1{,}506 \cdot 10^{-3}$ kg vaste deeltjes	$137{,}0 \cdot 10^{-3}$ kg koffie
Ø $4{,}5 \cdot 10^{-3}$ m	$1{,}416 \cdot 10^{-3}$ kg vaste deeltjes	$135{,}6 \cdot 10^{-3}$ kg koffie

$d_m = 60 \cdot 10^{-3}$ m



$C_4 = 0{,}003902889$
$k_4 = -0{,}381$

TU Delft

The taste model

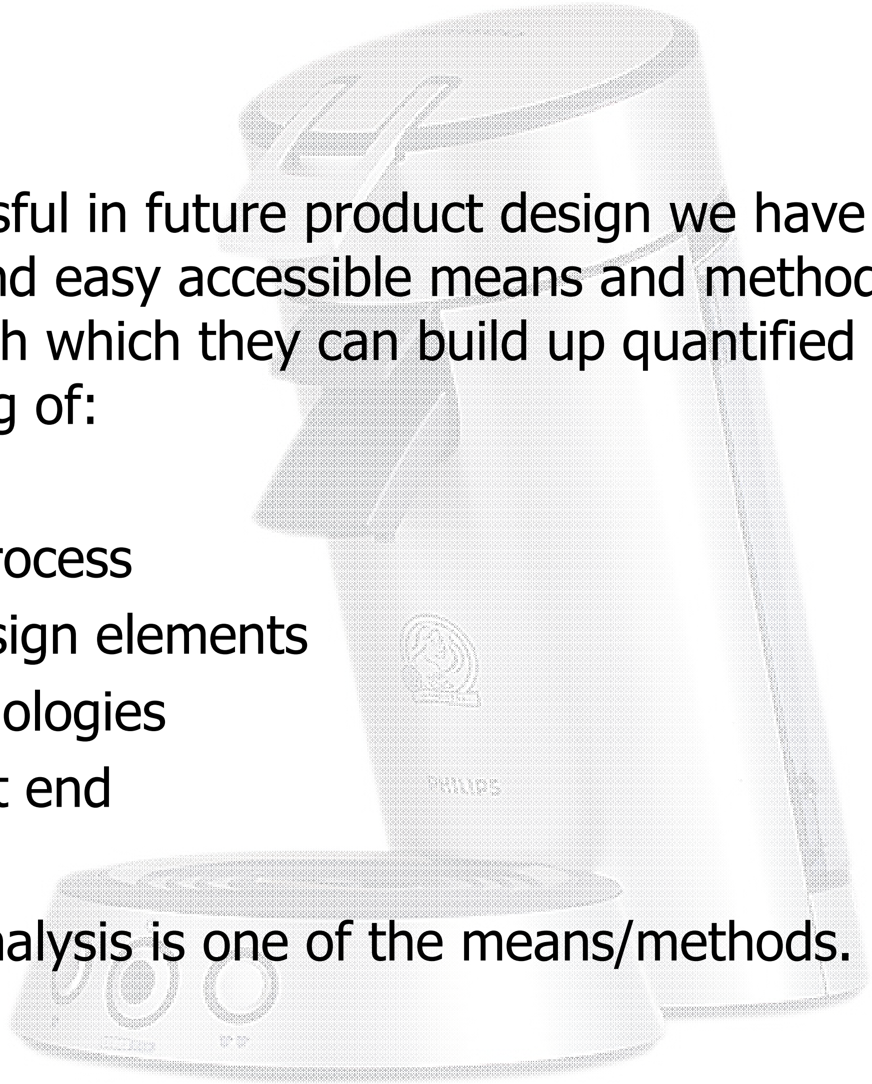
$$\frac{m_d}{m_w} = C \cdot \left[\frac{V_{md}}{d_m^3}\right]^{k_1} \cdot \left[\frac{d_p}{d_m}\right]^{k_2} \cdot \left[\frac{A_f}{d_m^2}\right]^{k_3} \cdot \left[\frac{d_s}{d_m}\right]^{k_4} \cdot \left[\frac{l_m}{d_m}\right]^{k_5} \cdot \left[\frac{m_m}{m_w}\right]^{k_6} \cdot \left[\frac{\kappa \cdot d_m^6 \cdot T_w}{a^3 \cdot m_w}\right]^{k_7} \cdot \left[\frac{d_m^5 \cdot p}{a^2 \cdot m_w}\right]^{k_8} \cdot \left[\frac{a \cdot t_c}{d_m^2}\right]^{k_9}$$

$$\frac{m_d}{m_w} = 2.00 \cdot 10^{29} \cdot \left[\frac{d_p}{d_m}\right]^{-0.623} \cdot \left[\frac{d_s}{d_m}\right]^{-0.381} \cdot \left[\frac{m_m}{m_w}\right]^{1.376} \cdot \left[\frac{d_m^5 \cdot p}{a^2 \cdot m_w}\right]^{-2.457}$$

$$\Leftrightarrow \frac{m_d}{m_w} = 2.00 \cdot 10^{29} \cdot d_p^{-0.623} \cdot d_s^{-0.381} \cdot m_m^{1.376} \cdot d_m^{-11.281} \cdot p^{-2.457} \cdot a^{4.914} \cdot m_w^{1.081}$$

DA is a good tool to come to a quantitative understanding of complex processes

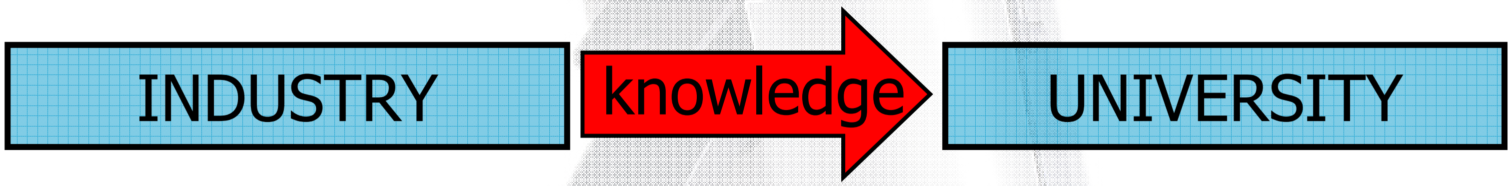
Conclusion



- To be successful in future product design we have to have knowledge and easy accessible means and methods for Product Designers with which they can build up quantified knowledge and understanding of:
  - primary process
  - critical design elements
  - new technologies
  - fuzzy front end
- Dimension Analysis is one of the means/methods.

Conclusion

- Actual in Industrial Design:



- Lets take the challenge: