

# Integrated design of modular products and processes with data mining techniques

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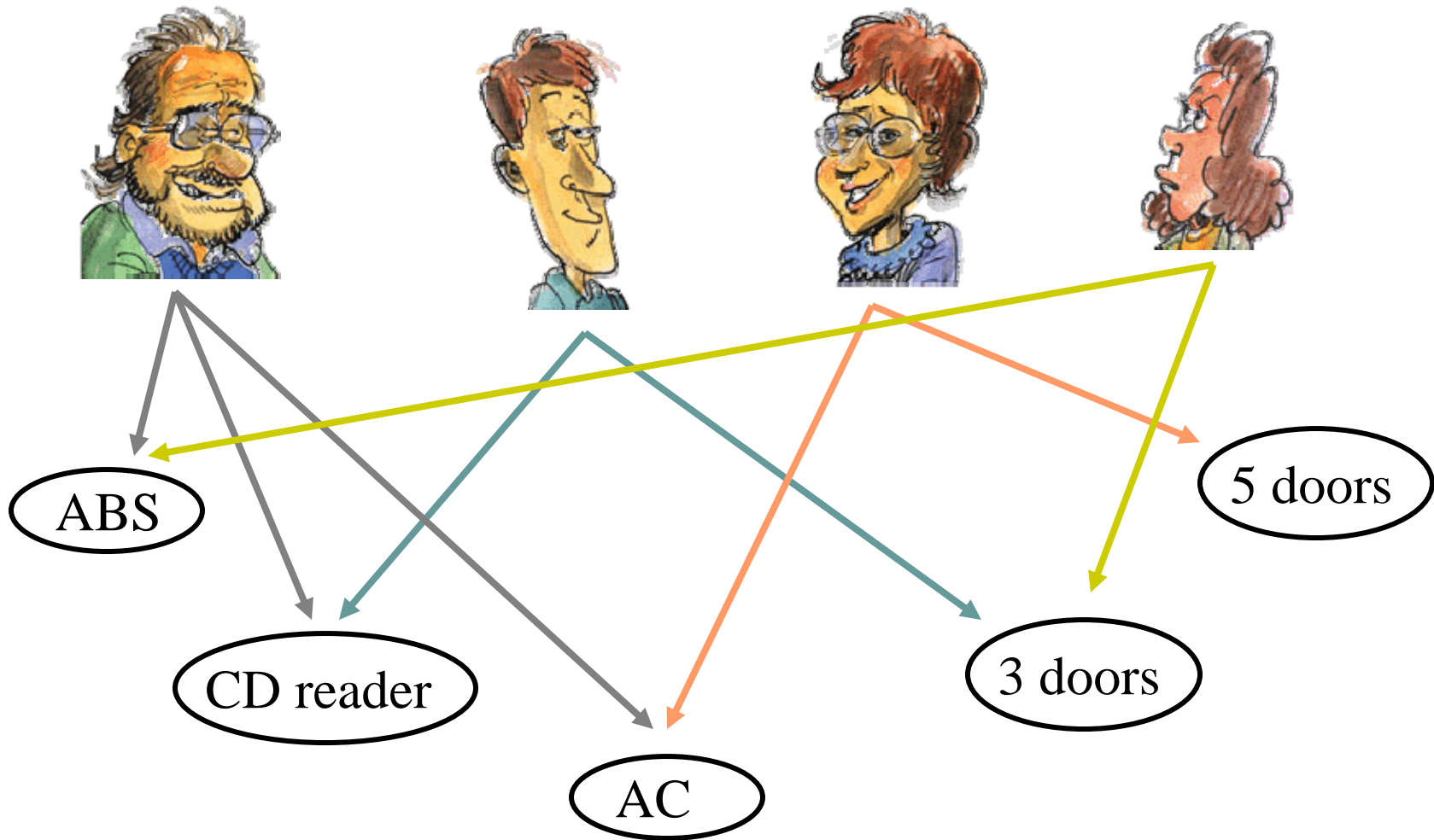
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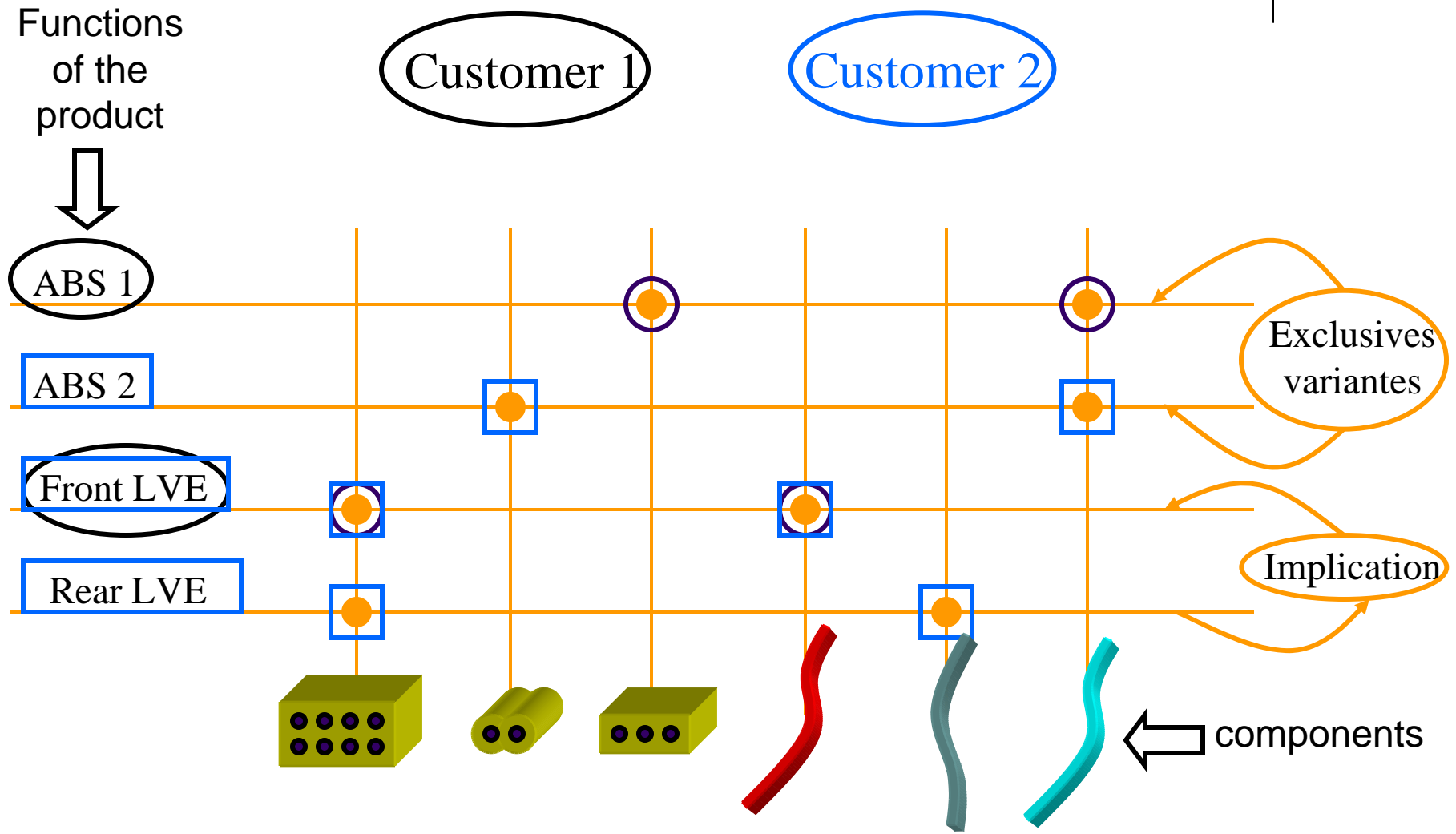
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# Introduction: Context of product diversity



# Product diversity



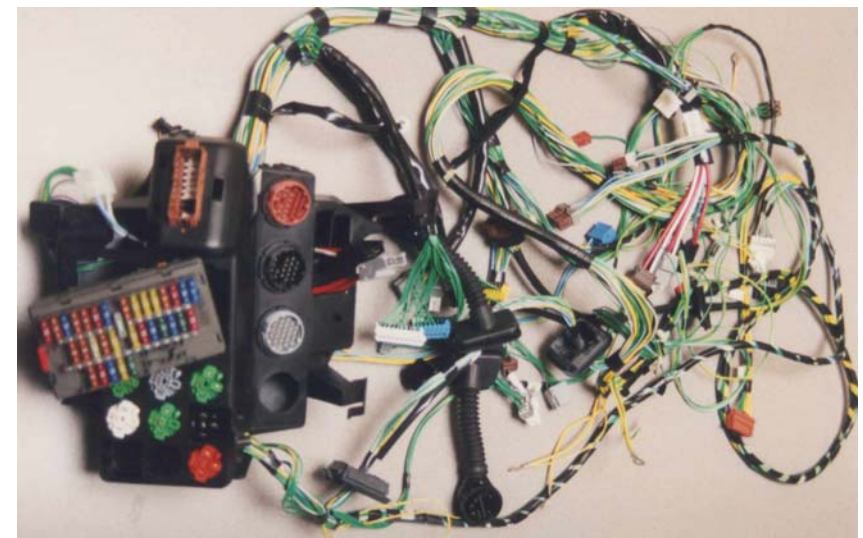
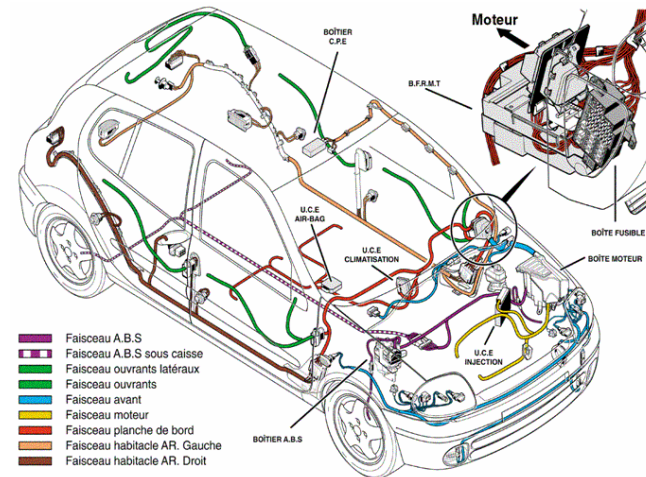
# Case study

- Automotive Wire Harness

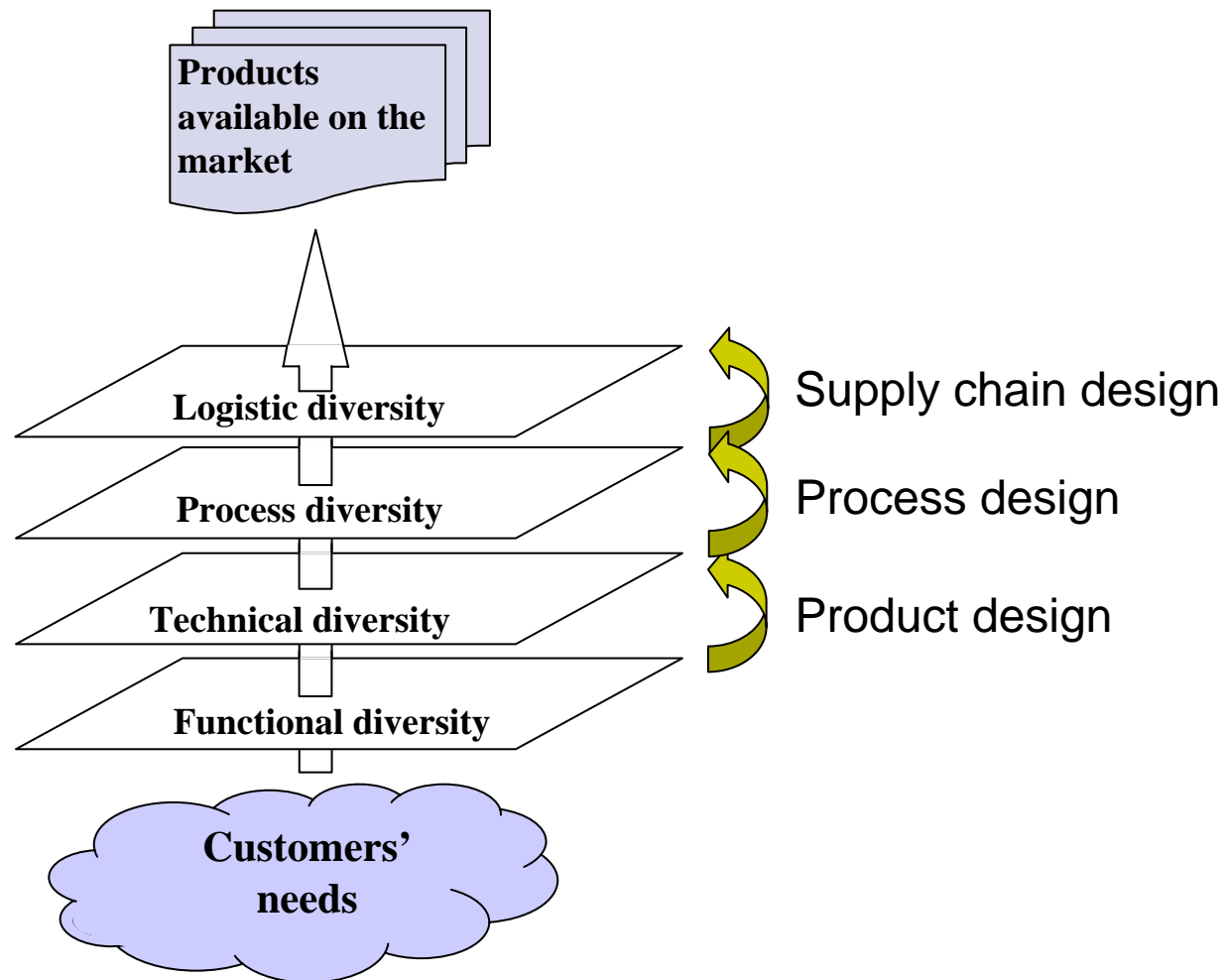
- many options and alternatives
- synchronous delivery
- manufacturing time > lead time
- 350 000 per year

- Diversity

- at the components level
  - 400 references of cables,
  - 120 connectors,
  - 50 derivations,
  - 30 soldering joints
- 15 different functions (1 to 9 versions)
  - a potential combinatory of **7 millions different wire harnesses !**



# Different levels of diversity



# Questions:

1. How to design a modular product architecture, with data mining tools, in order to rationalize the design and manufacturing of a product family?
2. How to take advantage of a modular product architecture on the manufacturing level?

# Outlines

- Design of product families
  - Strategies
  - Methodology
    - Functional requirements analysis
    - Creation of a functional structure
    - Creation of a technical structure
    - Search for valid solutions
    - Selection of a final solution
- Upgrades with data mining
  - Data mining
  - Data mining in modular design
    - Modular components
    - Modular products
    - Modular processes
- Conclusions and perspectives

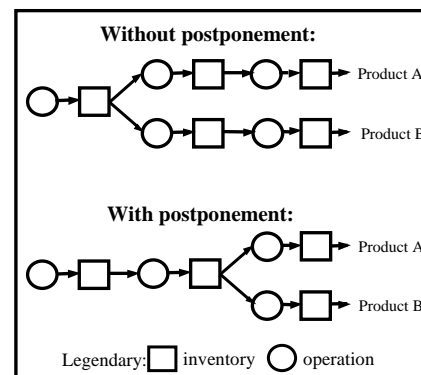
# Design of product families



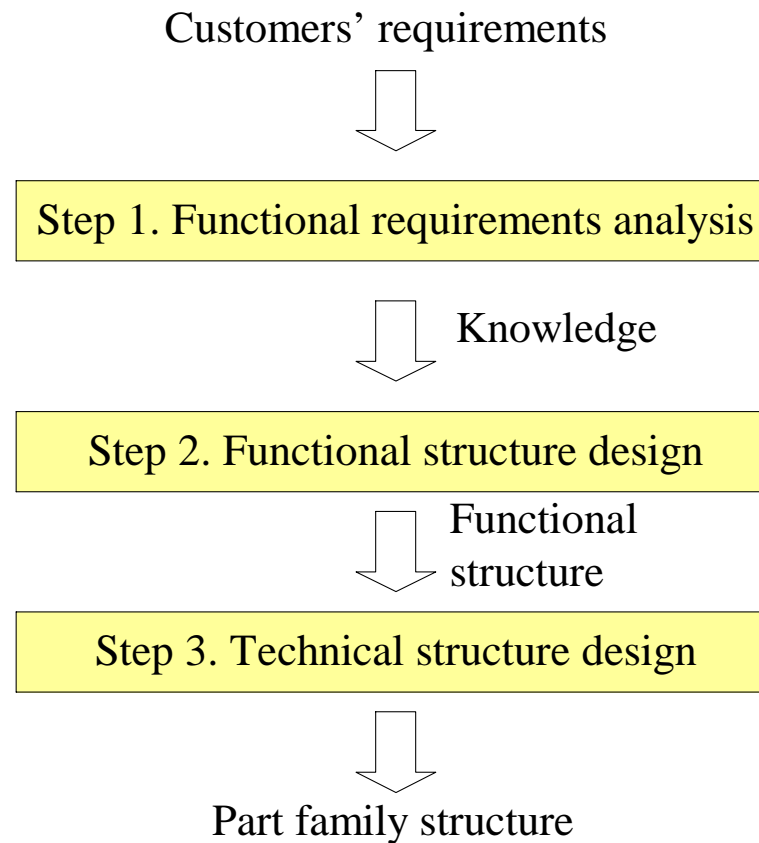


# Different strategies

- Design level
  - Standardization
    - Small diversity
    - Higher quality
  - Exact products
    - Huge diversity
  - Possibilities on
    - Components
    - Products
    - Processes
- Manufacture level
  - Production for stock
    - All references must be available in stock
    - Many unnecessary references to stock
  - Production on request
    - Important lead time
    - May be expensive
  - Assembly to order
    - Compromise



# Methodology



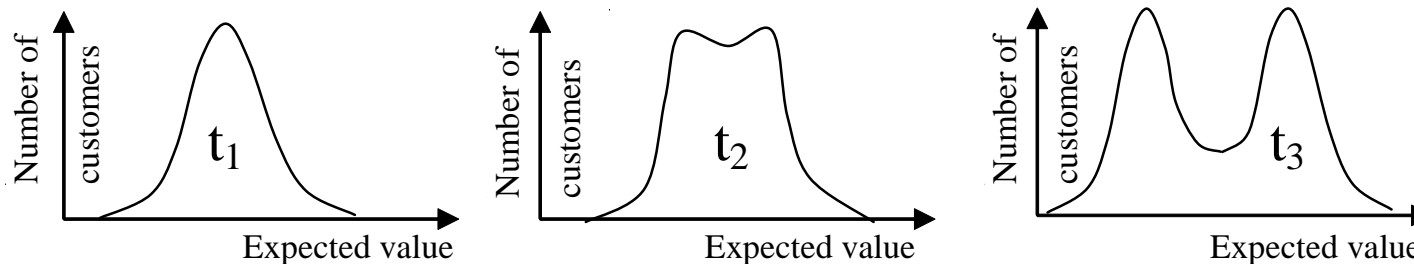
# Design of product families

- Functional requirements analysis
  - Product centered
  - Customer centered

*Customers' requirements at different times t1, t2, t3*

Time t <sub>1</sub>	description of the customer				Expectations for the product						
	age	sex	income	insurance	F1	F2	F3	F4	F5	F6	F7
Customer 1	35	F	L	yes	1		1	1			40
Customer 2	55	M	H	yes		1		1	1		40
Customer 3	40	M	M	yes	1	1		1		1	70
Customer 4	28	F	H	no	1		1				65
Customer 5	29	F	L	yes	1	1	1	1	1	1	75
Customer 6	50	M	H	yes		1			1	1	75
Customer 7	32	F	M	no	1			1		1	45
Customer 8	37	M	L	no	1		1				45
Customer 9	48	M	M	no	1	1	1	1	1	1	60
Customer 10	65	M	H	yes		1	1		1		65

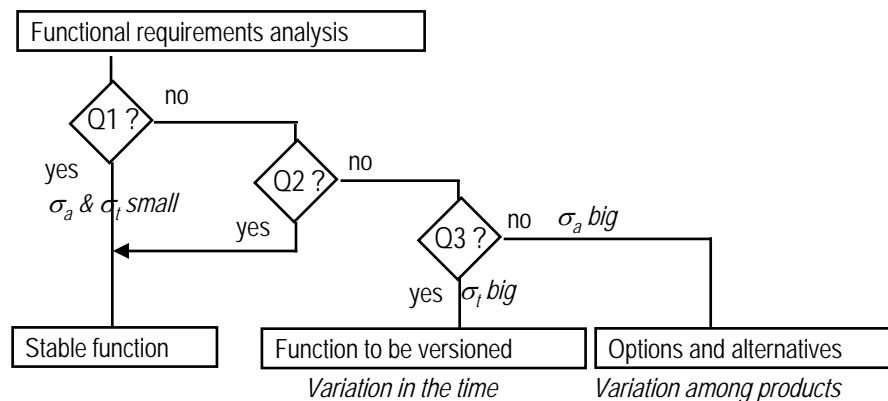
$\sigma_a$  (customer-dependence)  
 $\sigma_t$  (time-dependence)



*Variations in customers' requirements at time t1, t2, and t3*

# Design of product families

## • Creation of a functional structure

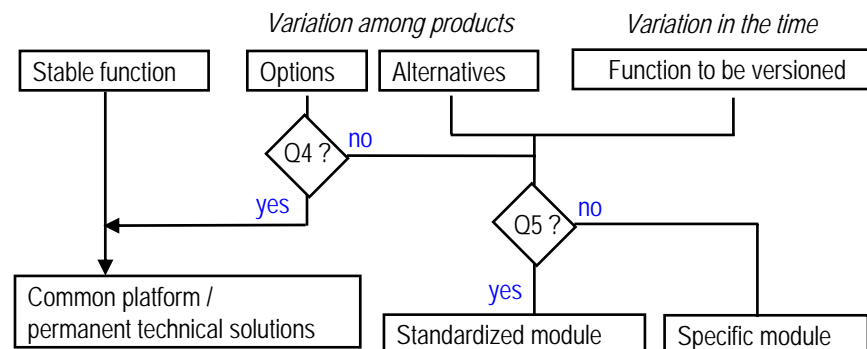


Q1: Is the function stable ?

Q2: Can the variation of the function be supported by a robust and inexpensive design?

Q3: Is the variation customer-dependant and/or time-dependant?

## • Creation of a technical structure



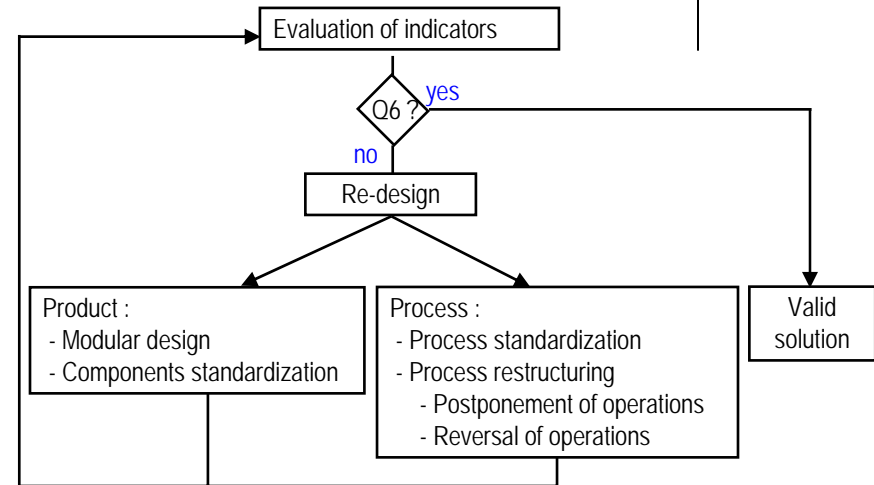
Q4: Is there a high demand and is the standardization cost low?

Q5: Is there a high association in the requirements and is the standardization cost low?

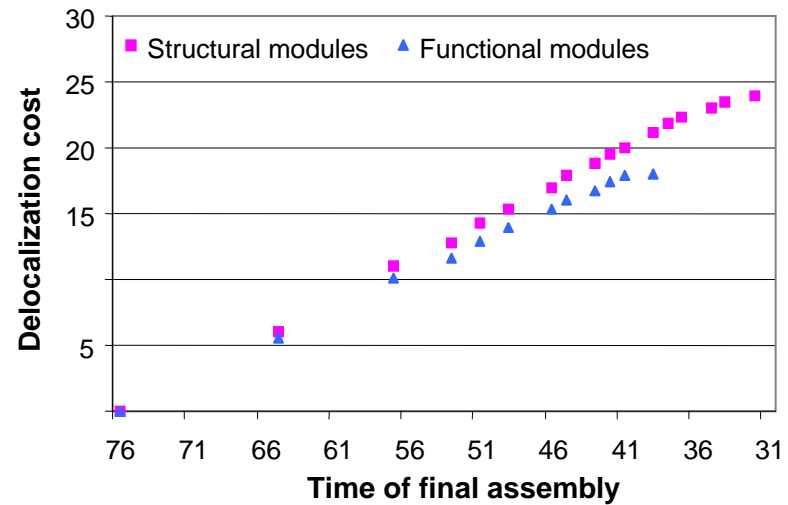
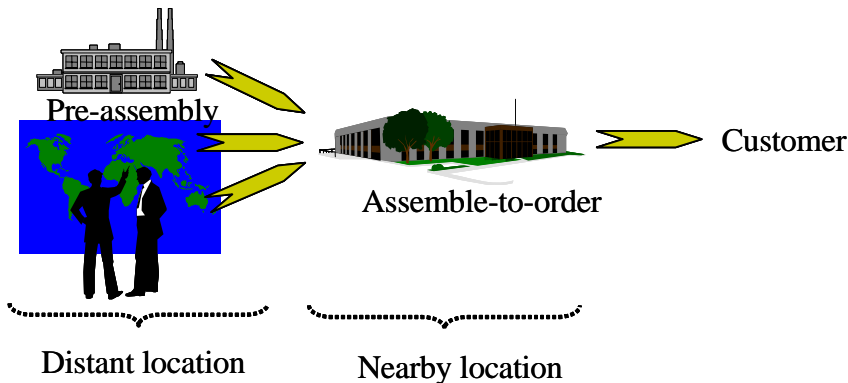
# Design of product families

- Search for valid solutions

Q6: Is the solution acceptable?



- Selection of a final solution



# Upgrades with data mining

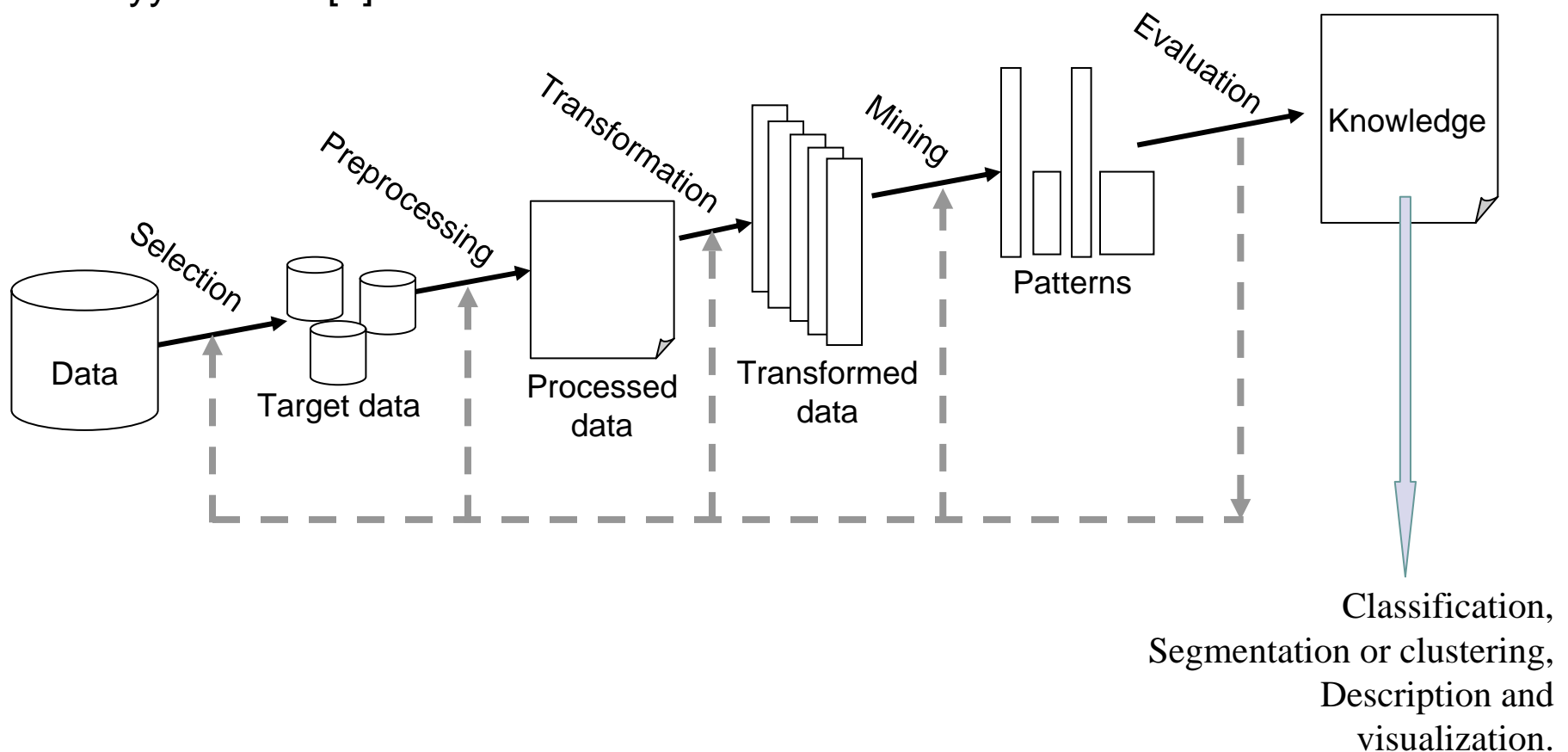


# Why data mining ?

- Data mining?
  - Anand and Büchner [1] defined data mining as the discovery of non-trivial, implicit, previously unknown, and potentially useful and understandable patterns from large data sets.
- Huge volume of data
  - Marketing, design, manufacturing...
  - Quality management, production management...
- Knowledge into the data
- The data is not sufficiently exploited

# The data mining process

Fayyad *et al.* [7]

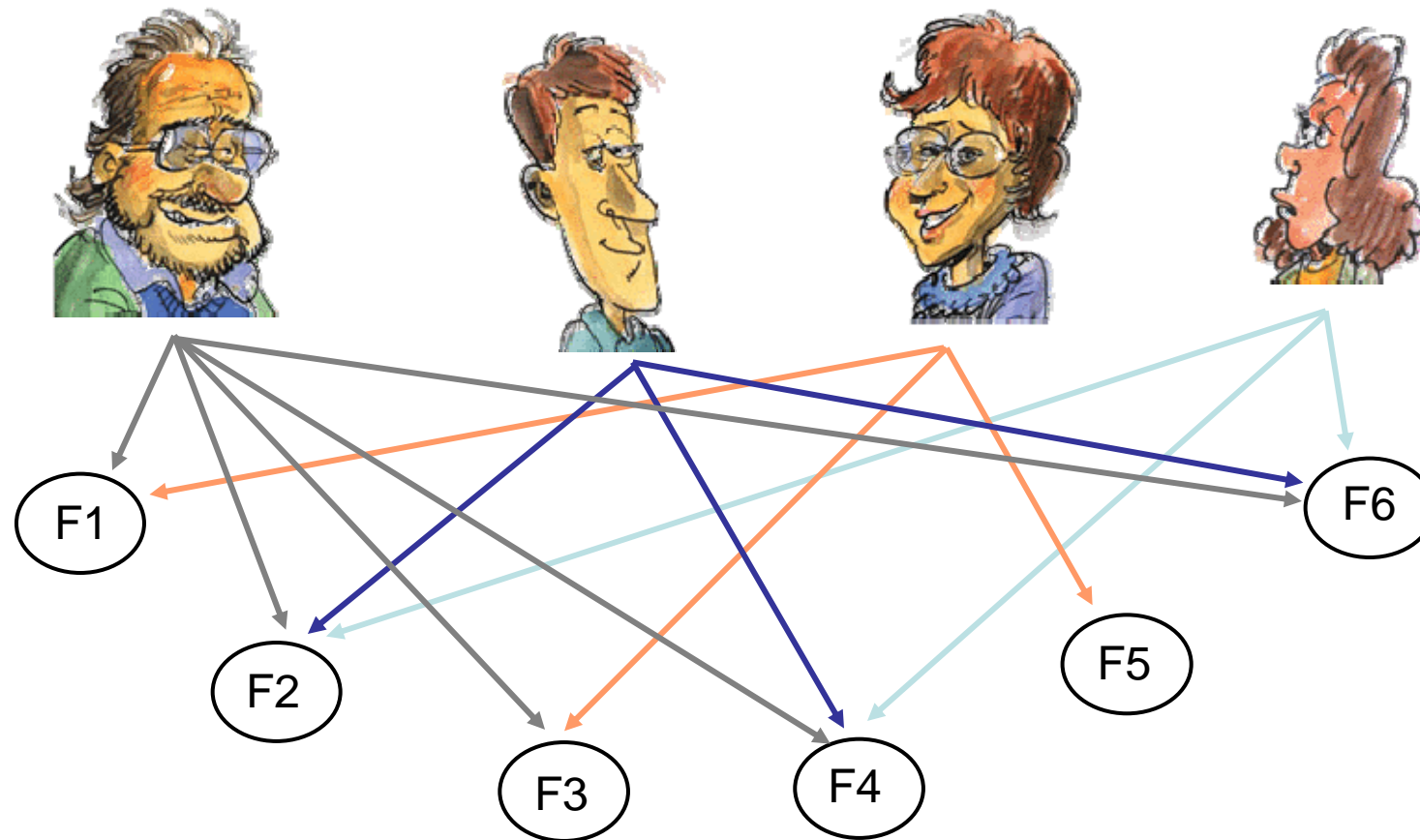




# Data mining in modular design

- Data mining techniques are useful in providing answers to the following questions:
  - Which modular components?
  - Which modular products?
  - Which modular processes?

# Modular components?



# Description of the customers and their requirements

	Customer Description				Product Requirements					
	Age	Gender	Income	Insurance	F1	F2	F3	F4	F5	F6
Customer 1	35	F	L	Yes	1		1	1		
Customer 2	55	M	H	Yes		1		1	1	
Customer 3	40	M	M	Yes	1	1		1		
Customer 4	28	F	H	No	1		1		1	
Customer 5	29	F	L	Yes	1	1	1	1	1	1
Customer 6	50	M	H	Yes		1			1	1
Customer 7	32	F	M	No	1		1	1		1
Customer 8	37	M	L	No	1		1	1		
Customer 9	48	M	M	No	1	1	1	1	1	1
Customer 10	65	M	H	Yes		1	1		1	

# Association rules

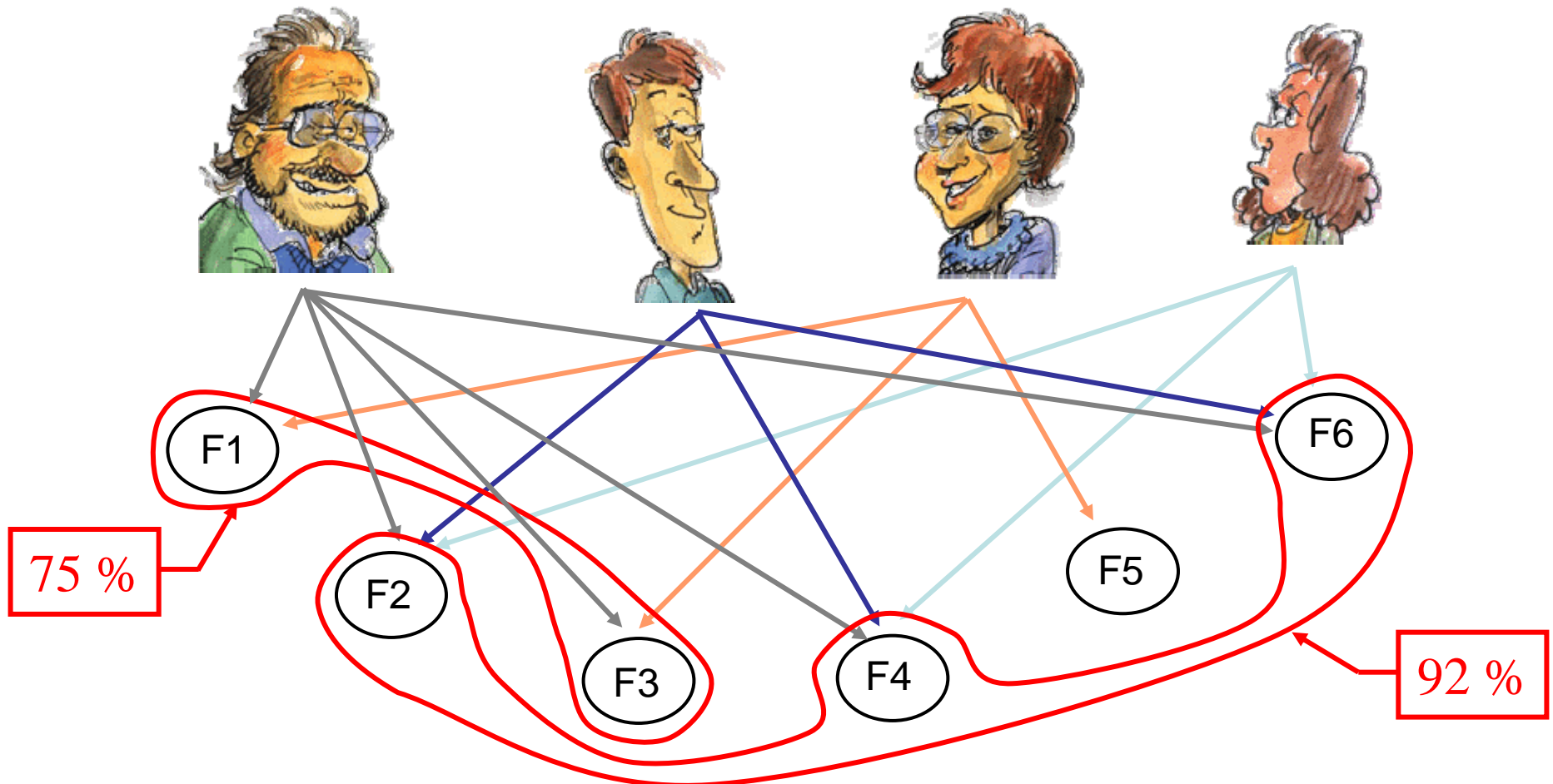
[Support, Confidence]

- **Rule 1.** F1 => F3, [62.5% (5/8), 80% (4/5)]
- **Rule 2.** (F2 & F4) => F6, [50 %, 100%]
- **Rule 3.** F5 => NOT F2, [37.5 %, 100%]

	F1	F2	F3	F4	F5	F6
Customer 1	1	1	1	1		1
Customer 2		1		1		1
Customer 3	1		1		1	
Customer 4		1		1		1
Customer 5	1		1		1	
Customer 6					1	
Customer 7	1	1		1		1
Customer 8	1		1			

- **Rule 1.** Suggests a standardized component supporting features F1 and F3. The standardized component {F1, F3} would meet the requirements {F1}, {F3} and {F1, F3}.
- **Rule 2.** This rule suggests the design of a standardized component {F2, F4, F6}.
- **Rule 3.** This rule implies that whenever F5 is present, F2 is not included, i.e., F2 and F5 should not be realized as one component.

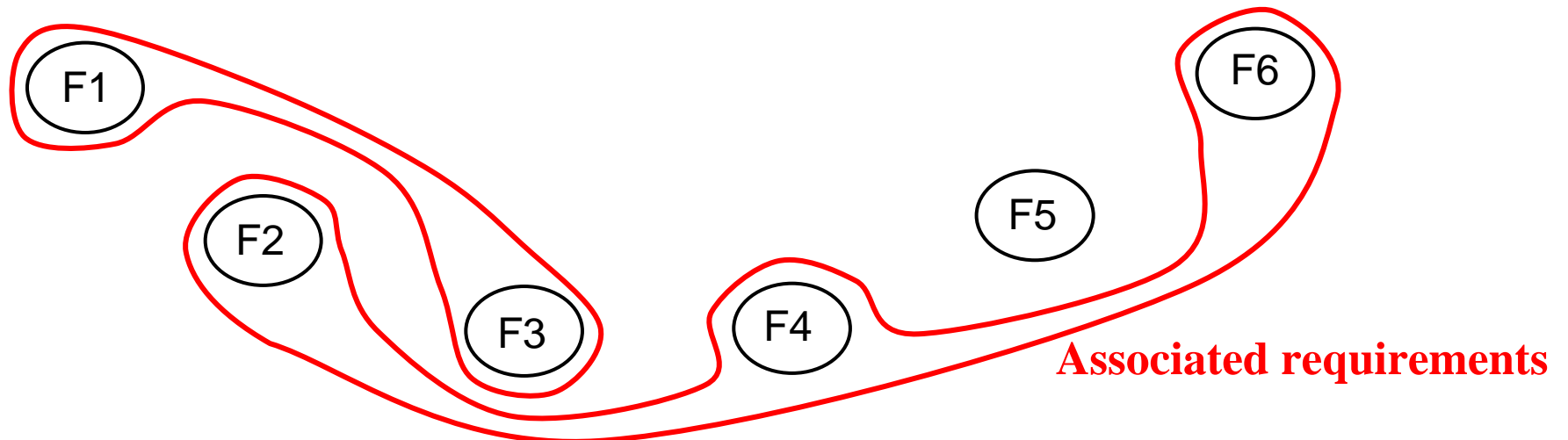
# Modular components



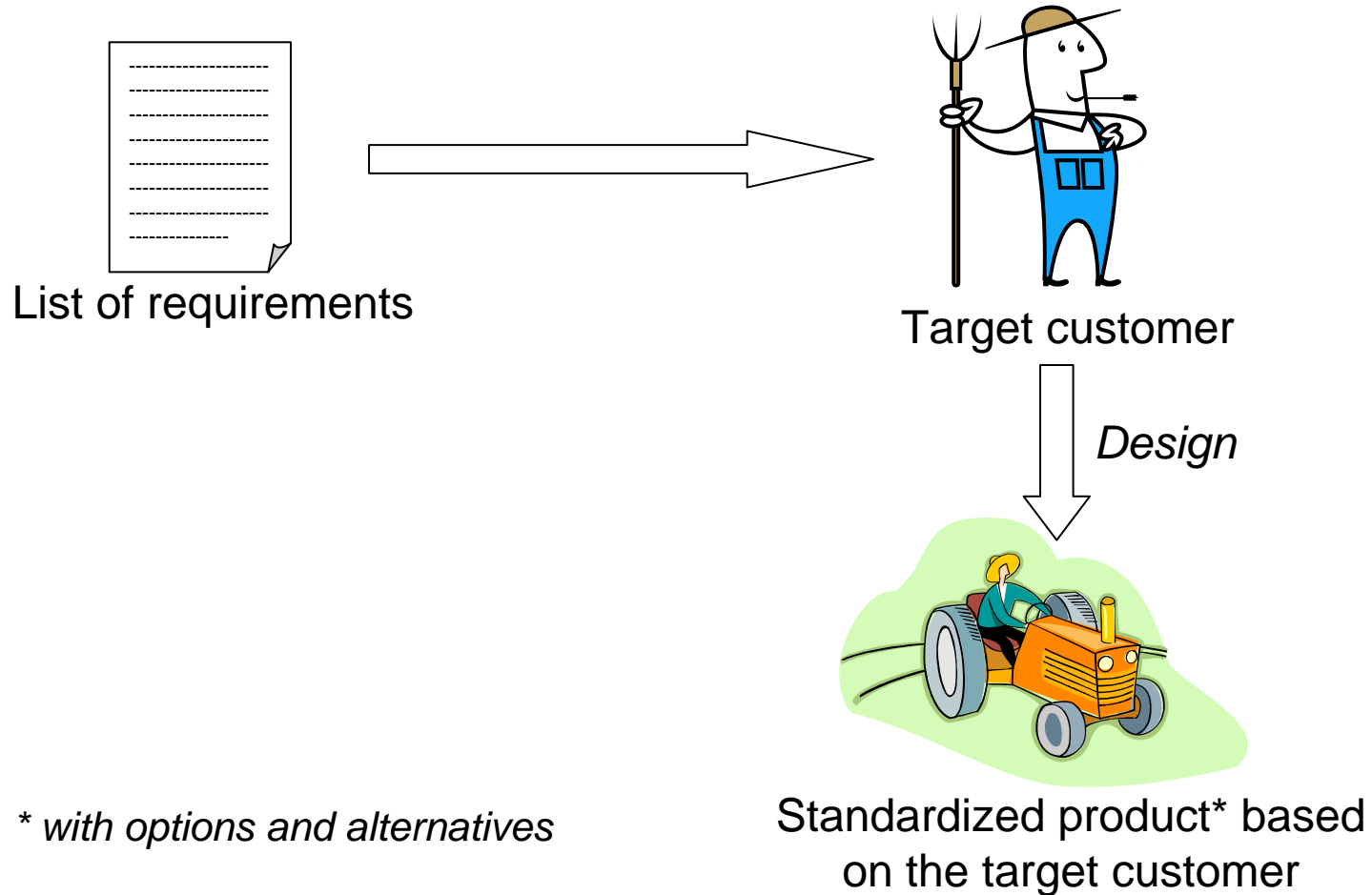
# Modular products?

- The following alternatives are considered:
  - The design of a standardized product for a large population of customers.
  - The design of different standardized products (How many? Which ones?).
  - The design of a standardized product for selected customers.

# Modular components



# Design of a standardized product for a large population of customers





# Modular products



F1

F6

F2

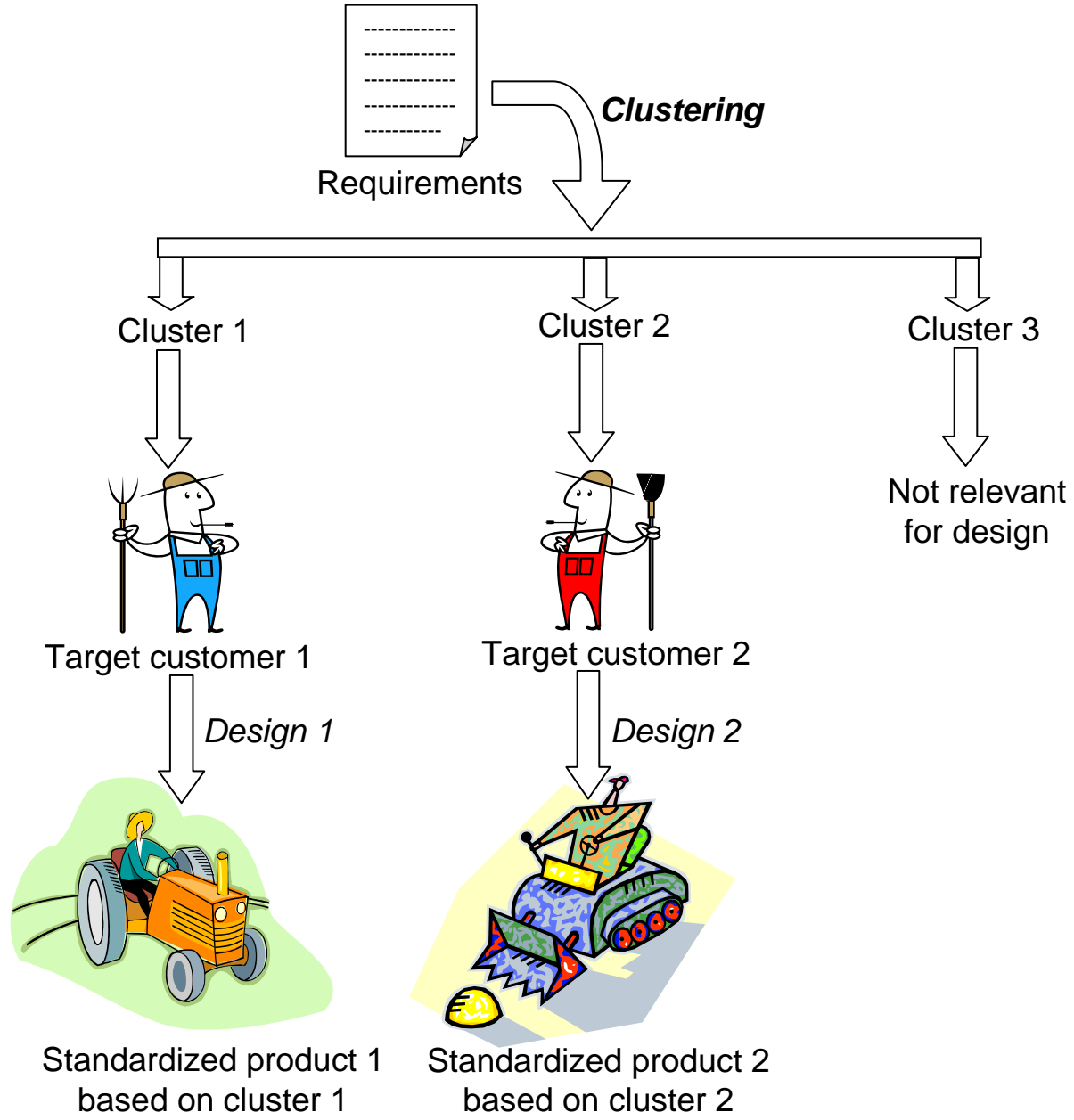
F5

F3

F4

**Similar customers**

# Design of different standardized products



	Customer Description				Product Requirements					
	Age	Gender	Income	Insurance	F1	F2	F3	F4	F5	F6
Customer 1	35	F	L	Yes	1	1	1	1		
Customer 2	55	M	H	Yes	1	1		1	1	
Customer 3	40	M	M	Yes	1	1	1	1		
Customer 4	28	F	H	No	1		1	1	1	
Customer 5	29	F	L	Yes	1	1	1	1	1	1
Customer 6	50	M	H	Yes		1			1	1
Customer 7	32	F	M	No	1		1	1	1	1
Customer 8	37	M	L	No	1		1	1		
Customer 9	48	M	M	No	1	1	1	1	1	1
Customer 10	65	M	H	Yes		1	1		1	1

		Customer Requirement					
		F1	F2	F3	F4	F5	F6
Cluster 1 (50%)	Customer 1	1		1	1		
	Customer 3	1	1		1		
	Customer 4	1		1		1	
	Customer 7	1		1	1		1
Cluster 2 (30%)	Customer 2		1		1	1	
	Customer 6		1			1	1
Cluster 3 (20%)	Customer 5	1	1	1	1	1	1
	Customer 9	1	1	1	1	1	1

Design 1

Design 2

Design 3

# Standardized products?



F1

F2

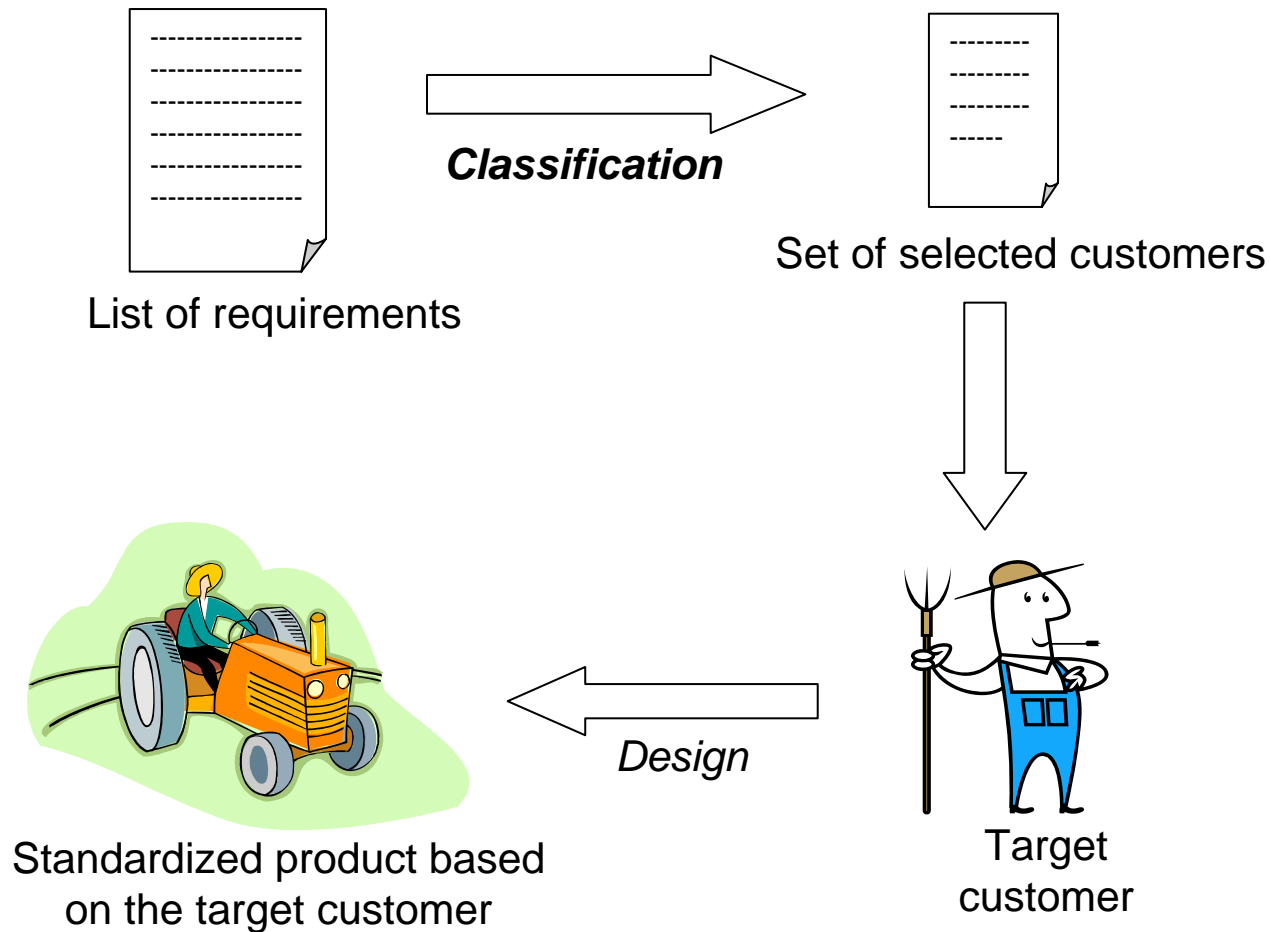
F3

F4

F5

F6

# Design a unique standardized product for selected customers



# Résumé



F1

F2

F3

F4

F5

F6

**Associated requirements**

**Similar customers**

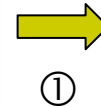
**Target customers**

# Modular processes?

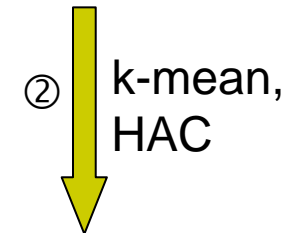
	Part Description						Manufacturing Process					
	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6
Part 1	1	1		1		1	M1	M4	M7	M2		
Part 2		1	1		1	1	M5	M2	M1	M4		
Part 3	1			1		1	M4	M3	M8			
Part 4		1			1		M2	M7				
Part 5		1	1		1		M5	M2	M1	M4		
Part 6		1		1		1	M4	M7	M2			
Part 7	1		1		1		M1	M4	M7	M5	M2	

# Data transformations and treatment to identify departments

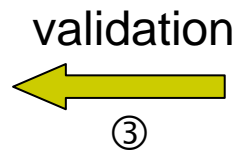
	Ref #	Qty/ week	Manufacturing process						
List of products	123	5	M1	M2	M4	M7			
	234	7	M4	M7	M2	M1			
	345	4	M5	M3	M6				
	567	8	M6	M5	M3	M7			
	...	...	...						



	Ref	Manufacturing process									
List of products		M1	M2	M3	M4	M5	M6	M7	...	Mn	
	123	1	1		1			1			
	234	1	1		1			1			
	345			1		1	1				
	567			1		1	1	1			
	...	...	...								



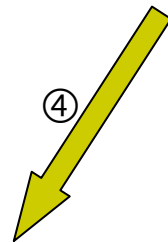
Dept 1:	machines {M1, M2, M4, M7}
Dept 2:	machines {M3, M5, M6}
...	



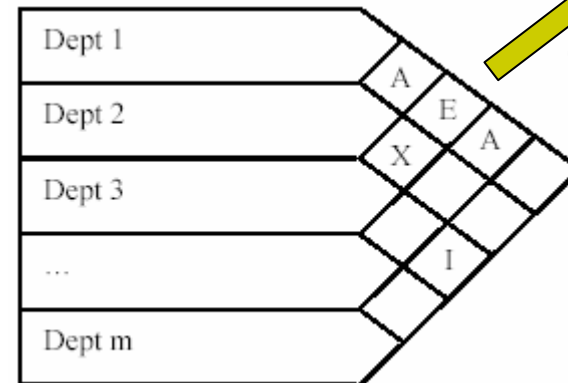
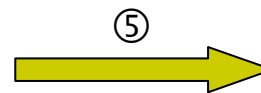
Cluster 1:	products {#123, #234, ...}
Cluster 2:	products {#345, #567, ...}
...	

# Computation of an activity relationship diagram

#123	#234	#345	#567
M1-Dept 1	M4-Dept 1	M5-Dept 2	M6-Dept 2
M2-Dept 1	M7-Dept 1	M3-Dept 2	M5-Dept 2
M4-Dept 1	M2-Dept 1	M6-Dept 2	M3-Dept 2
M7-Dept 1	M1-Dept 1		M7-Dept 1

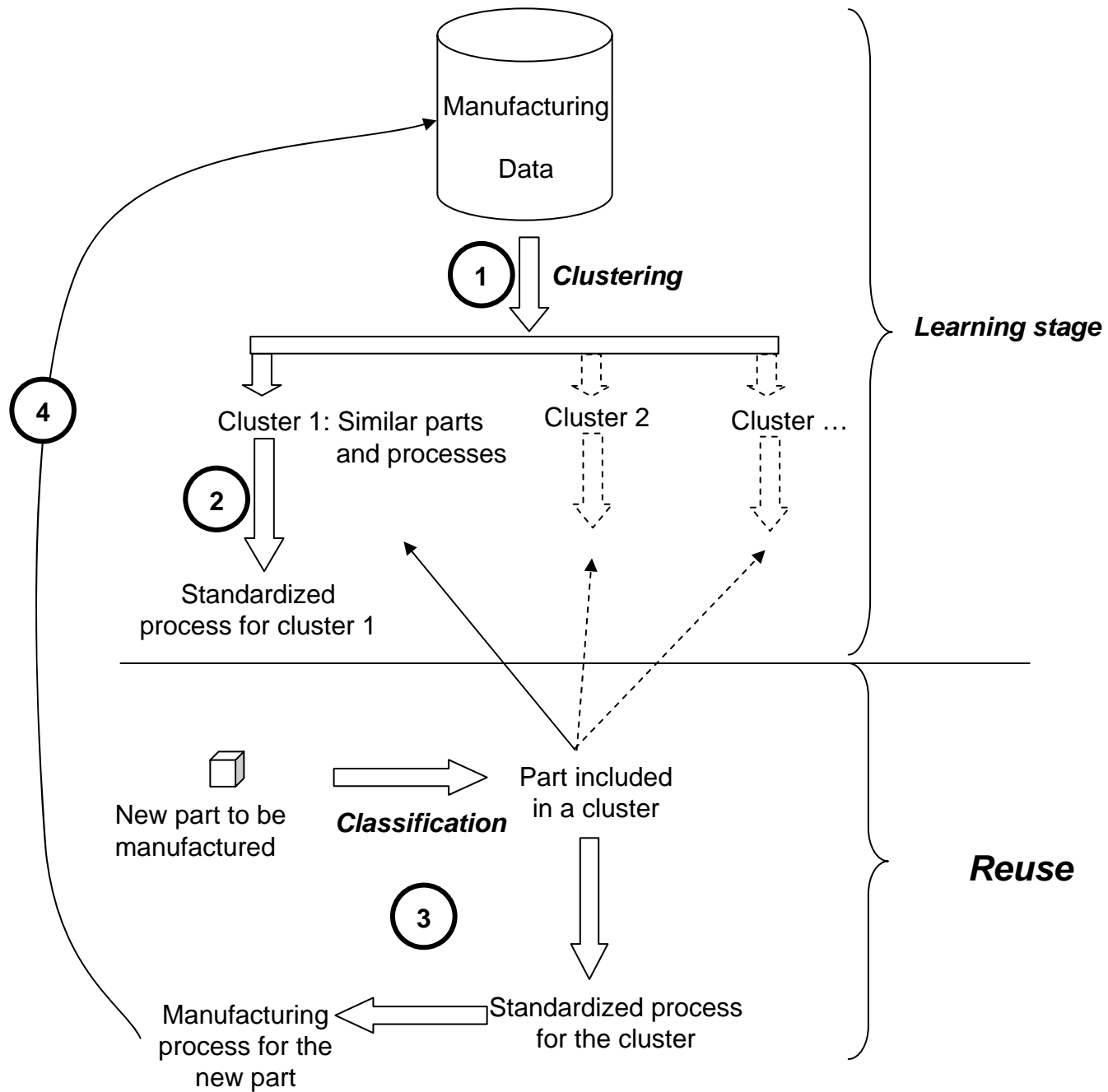


List of products	Ref #	Qty/ week	Manufacturing process		
	123	5	Dept 1		
234	7	Dept 1			
345	4	Dept 2			
567	8	Dept 2	Dept 1		
...	...	...			



Layout





# Conclusions and perspective

- Data mining may be useful in different activities in the design of modular components, products and/or processes
- Examples have been outlined
  - Associated requirements
  - Similar customers
  - Target customers
  - Manufacturing processes
- Further works may consider improvements linked to the supply chain