Conceptualization I

Lecture 4

Schedule

Week nr.	Date	Lecture (Wednesday)			Lab (Wednesday)		Comment
1	09.04.	1	General information		1	Lab	
2	09.11.	2	Development methods		2	Lab	Online
3	09.18.	3	Design goals and requirements		3	Lab	
4	09.25.	4	Conceptualization I		4	Lab	
5	10.02.	5	Design guidelines		5	Lab	
6	10.09.	6	Testing strategies in the automotive industry		6	Lab	
7	10.16.	T1	Midterm exam I.				
8	10.23.	B	National holiday				
9	10.30.	7	System level testing		T1 R	Exam 1 - Retake	Online
10	11.06.	8	Performance and reliability testing		7	Lab	
11	11.13.	9	Troubleshooting and error calculation		8	Lab	
12	11.20.	10	Project management		9	Lab	Online
13	11.27.	T2	Midterm exam II.				
14	12.04.	T2R	Exam 2 - Retake				

Agenda

- Overview of the phase
- Problem definition and requirements analysis
- Ideation Techniques
- Function Analysis
- Concept Generation
- ~~Life Cycle Analysis Introduction (LCA)~~
- Case studies and examples
- Q & A

Overview of the phase

Case study - NonFunctional

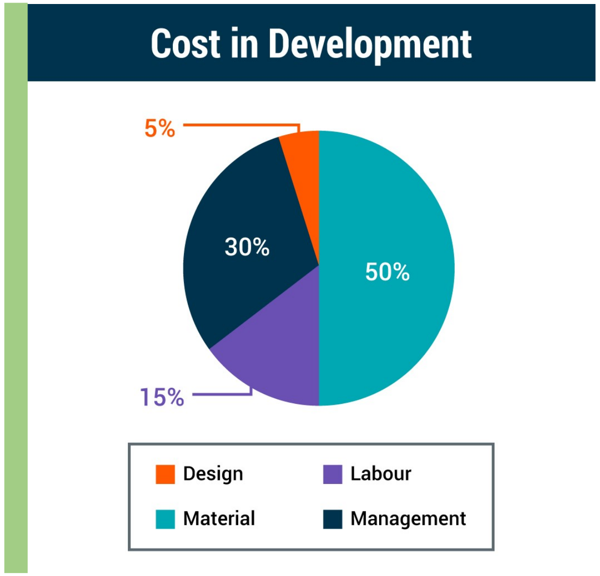
Requirement group	Requirement	Dimension	Comment
Efficiency			
Modifiability	Equity		BoP
Transfersibility			Backward compatiblity
Maintainability			Timeslots, costs etc
Environmental			Full lifecycle
Facility / Security			Equipment needed, signs, etc
Transportation			UN38.3, specs
Privacy, data security			
Personnel &trainings			
Risk acceptance			
Documentation			Manual, reports at maintenance

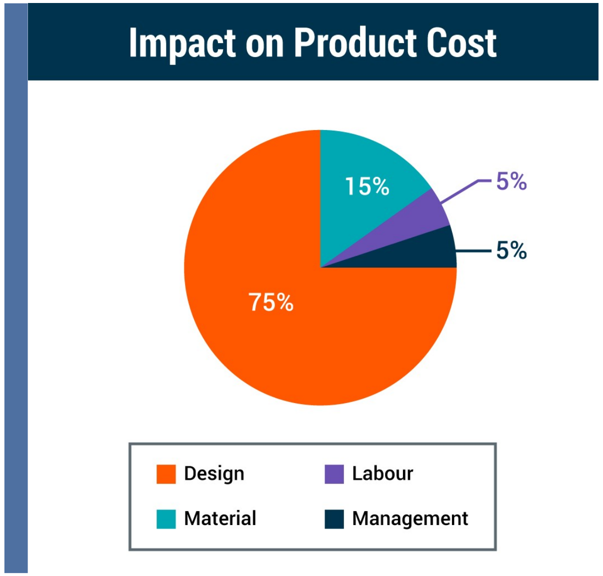
https://www.racecar-engineering.com/tech-explained/how-to-design-a-motorsport-battery-in-7-steps/

UN38.3 PASSED Transport Safety Certified

- We have the specs…
- Objective: Understand and translate requirements into functional specifications while organizing them into a structured framework.
- This includes recognizing redundancies between functions and requirements, and the ability to abstract and conceptualize, leading to innovative solutions. All of this is done with a holistic consideration of the entire product lifecycle.

Importance of conceptual design





https://www.ttelectronics.com/blog/design-for-excellence/ ;

Problem definition and requirements analysis

- Identifying and understanding the problem or need.
- Translating requirements into design goals and constraints.
- We are over the ‚Why?'.
  - Focus on ‚How?' and ‚What'?

Problem definition and requirements analysis

BME Automotive Technologies

- Identifying and understanding the problem or need.

Needs

- Develop an affordable EV that offers a practical range for daily urban commuting (e.g., 150-200 km per charge).
  - Compact size for easy parking and maneuverability in crowded city streets.
  - Low maintenance and operating costs.
  - Compliance with environmental regulations and incentives for EVs.

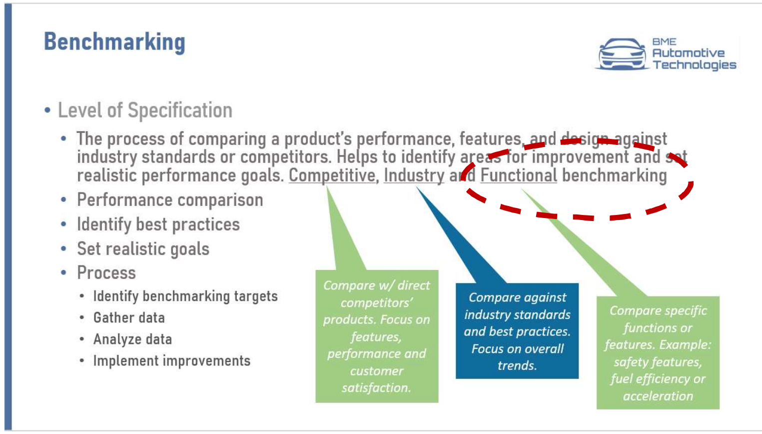
Stakeholders' insights

- Customers: Want a reliable, low-cost vehicle with sufficient range and minimal charging time.
- City Planners: Seek to reduce urban pollution and support sustainable transportation.
- Regulatory Bodies: Enforce emissions standards and promote the adoption of EVs.

Problem definition and requirements analysis

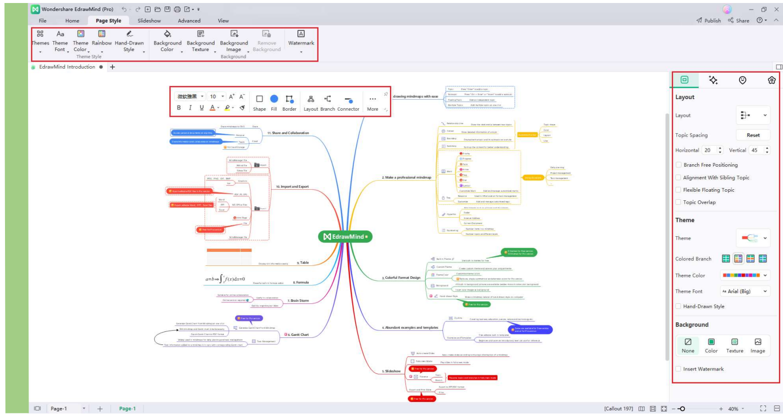
- Translating requirements into design goals and constraints.
  - Functional Requirements:
    - Battery Range: Must provide at least 150-200 km per charge.
    - Charging Time: Capable of fast charging (e.g., 80% charge within 30 minutes).
    - Vehicle Dimensions: Compact size, not exceeding 4 meters in length.
  - Non-Functional Requirements:
    - Affordability: Target price under $25,000.
    - Safety: Must meet all safety standards, including crash test ratings.
    - User Experience: Easy-to-use infotainment system and comfortable seating for four passengers.
  - Design Goals Derived from Requirements:
    - Develop a battery that balances cost, weight, and energy density to achieve the desired range.
    - Implement lightweight materials and a streamlined design to improve efficiency.
    - Incorporate advanced safety features without significantly increasing costs.
    - Design a compact vehicle body that maximizes interior space while remaining easy to park and maneuver.

Ideation Techniques



- Functional benchmarking
- Brainstroming
  - Creative group activity where participants generate a wide range of ideas and solutions to a problem without judgement or criticism.
  - Used in the early stages of design to explore a broad range of concepts, such as new vehicle features or innovative design elements.
- Mind Mapping
  - A visual tool that helps organize thoughts and ideas around central concept.
  - Structuring ideas generated during brainstorming, identifying relationshops between design goals.
- Scamper
  - Structured technique that prompts idea generation through seven different approaches.
- TRIZ
  - Description: A problem-solving methodology that uses principles derived from the study of patterns in inventions and innovations. Focuses on eliminating contradictions and finding innovative solutions by applying established principles and inventive strategies. Provides a systematic approach to innovation, encouraging the use of proven strategies to overcome technical challenges. Application: Utilized in overcoming complex design challenges in automotive engineering, such as improving performance while reducing weight, or enhancing safety features without increasing costs.

Ideation Techniques



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https://www.edrawmind.com/article/how-to-make-a-mind-map.html;

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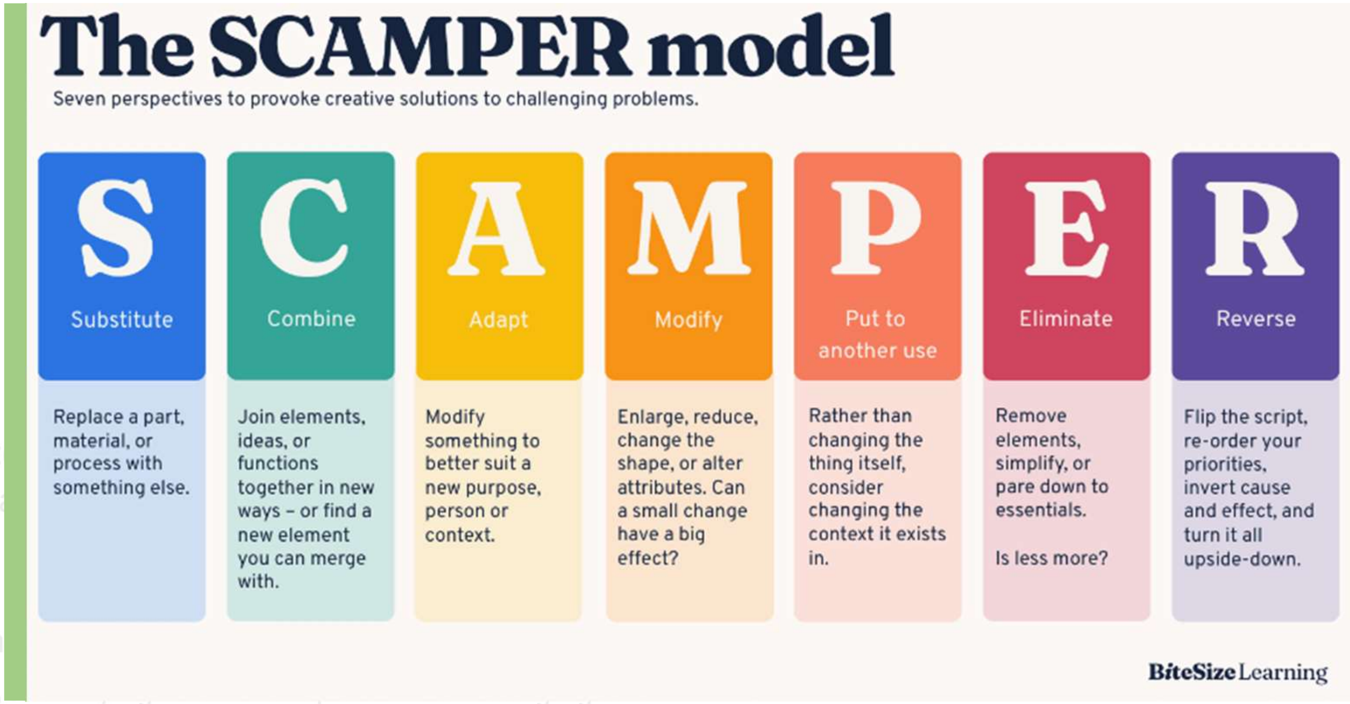

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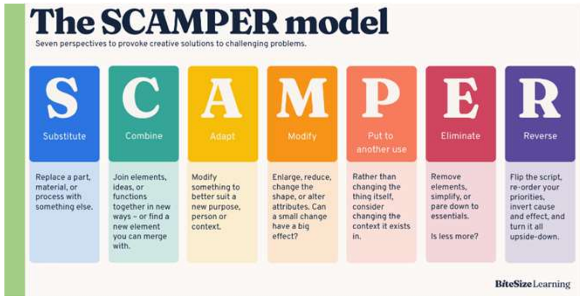
https://www.bitesizelearning.co.uk/resources/scamper-model-creativity

Scamper

- Substitute
  - How can we substitute the tools or technologies with stg more advanced or less conventional?
- Combine
  - Which two or more components of our offerings can we merge to create novel or more comprehensive solution?
- Adapt
  - What existing solutions in other fields or industries can we adapt to address our challenges?
- Modify
  - How can we change the design, features, or delivery of our product or service to enhance its appeal or functionality?
- Put to another use
  - In what unconventional ways can our product, service, or process be used, and how can we promote these alternative uses?
- Eliminate
  - What features, processes, or elements of our offering can be removed without compromising value, perhaps even simplifying or improving the end result?
- Reverse
  - What if we reversed our target audience's expectations—how would that change our approach or offering?



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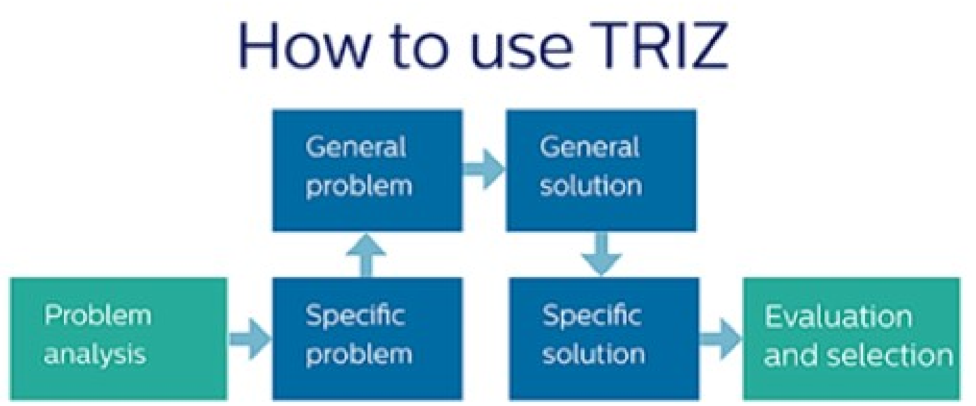

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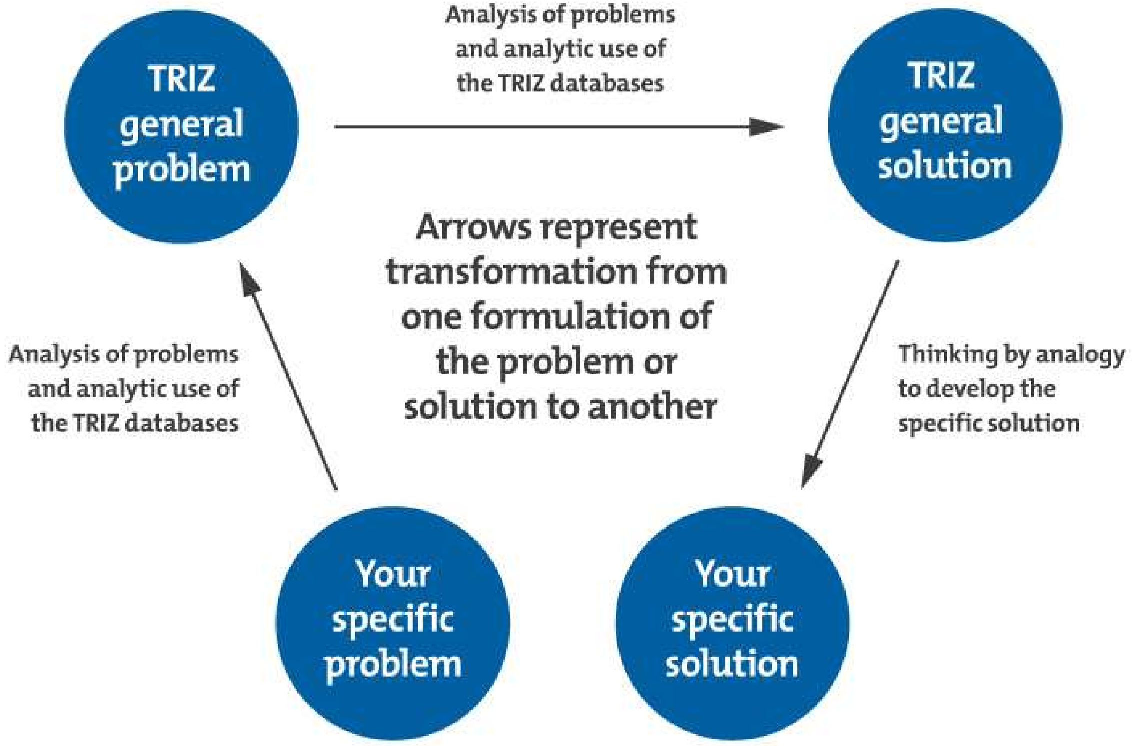
https://www.edrawmind.com/article/how-to-make-a-mind-map.html;

TRIZ

- Inventive problem:
  - A problem whose solution raises a new problem.
  - It leads to a compromise, which is not the ideal solution.
  - The TRIZ method of inventive problem solving focuses on resolving contradictions. The foundation of TRIZ is patent analysis (problems, contradictions, and solutions).
- This describes the essence of TRIZ (Theory of Inventive Problem Solving), which is aimed at systematically overcoming contradictions to avoid compromises and achieve innovative solutions.

TRIZ



https://www.linkedin.com/pulse/analysis-triz-implications-its-application-lean-six-stewart-lssmbb;

TRIZ - Example

Example to Introduce TRIZ Ideation Technique in the Automotive Industry

Example: Reducing Vehicle Weight Without Compromising Safety

Context:Automotive manufacturers are constantly challenged to reduce the weight of vehicles to improve fuel efficiency and reduce emissions. However, reducing weight must not compromise the vehicle's safety, which is a critical requirement.

Problem:How can we reduce the weight of a car without reducing its structural integrity and safety features?

1. Identify Contradiction: The contradiction here is that reducing the car's weight (a positive outcome) traditionally leads to a decrease in the car's structural strength and safety (a negative outcome).

2. Use TRIZ Principles:
   - Principle 1: Segmentation
   - Solution: Instead of using large, heavy metal sheets for the car's body, segment the structure into smaller, modular components made from lighter materials like aluminum or high-strength plastic composites.

https://www.edrawmind.com/article/how-to-make-a-mind-map.html;

TRIZ - Example

- Principle 15: Dynamics
- - Solution:Incorporate materials and designs that can absorb and distribute impact energy more efficiently. For example, crumple zones in modern vehicles are designed to deform in a controlled manner during a crash, absorbing the impact energy and reducing the force transmitted to occupants.

- Principle 40: Composite Materials
  - Solution: Use composite materials that combine lightweight characteristics with high strength, such as carbon fiber reinforced polymers (CFRP). These materials provide the necessary structural integrity while significantly reducing weight.

Outcome: - The application of TRIZ principles led to the development of lighter vehicles that maintain or even enhance safety. For example, modern race cars often use CFRP for their chassis, significantly reducing weight while improving safety and performance.

Real-World Example:
- The BMW i3 is a prime example of using lightweight composite materials. The car uses a carbon fiber reinforced plastic (CFRP) body, which is lighter than steel but provides high strength and safety. This innovative approach allows the vehicle to be more energy-efficient without compromising on safety standards.

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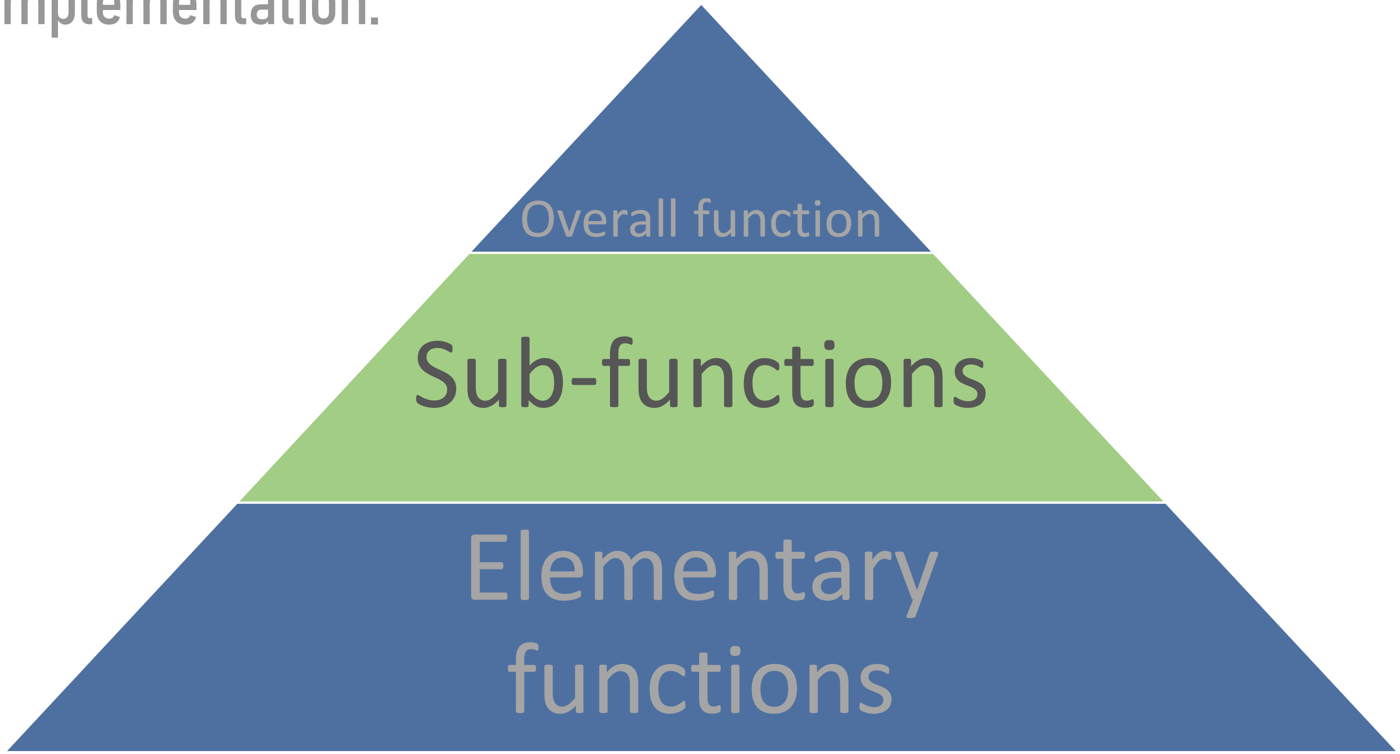
Function Analysis

- Functions
  - Economic
  - Technical
  - Psychological
  - Sociological
  - Documentary

Function Analysis

- A causal relationship between a specified input and output, abstracted from the particular implementation.



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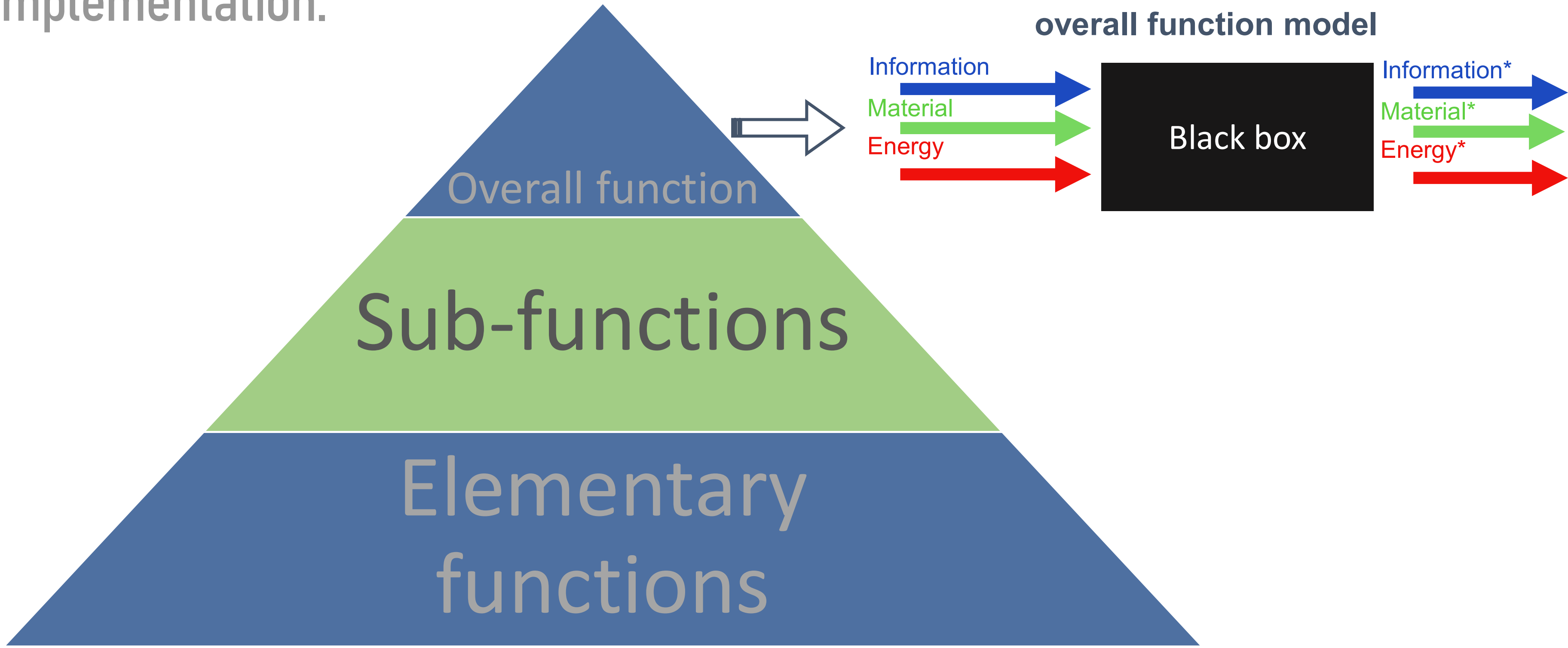

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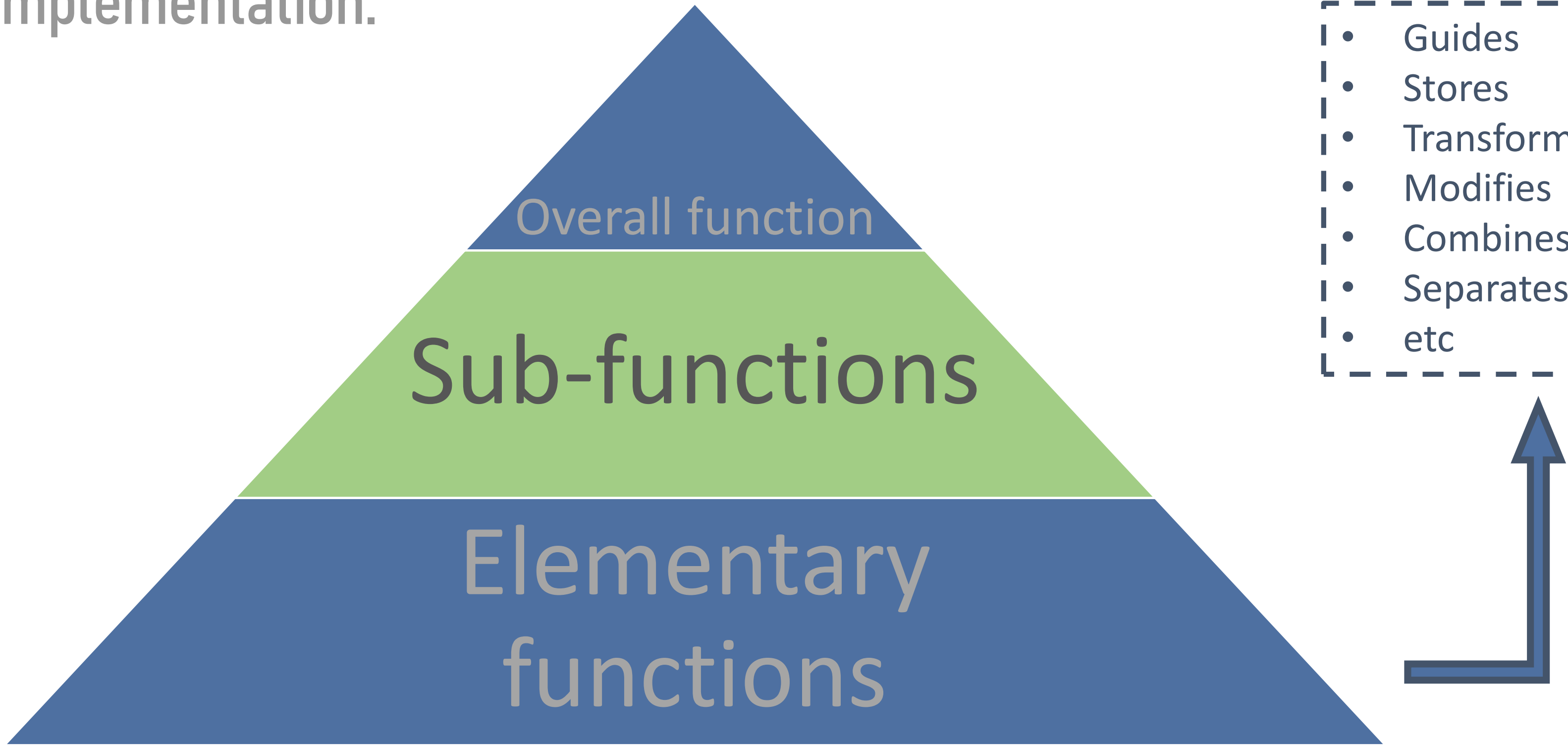
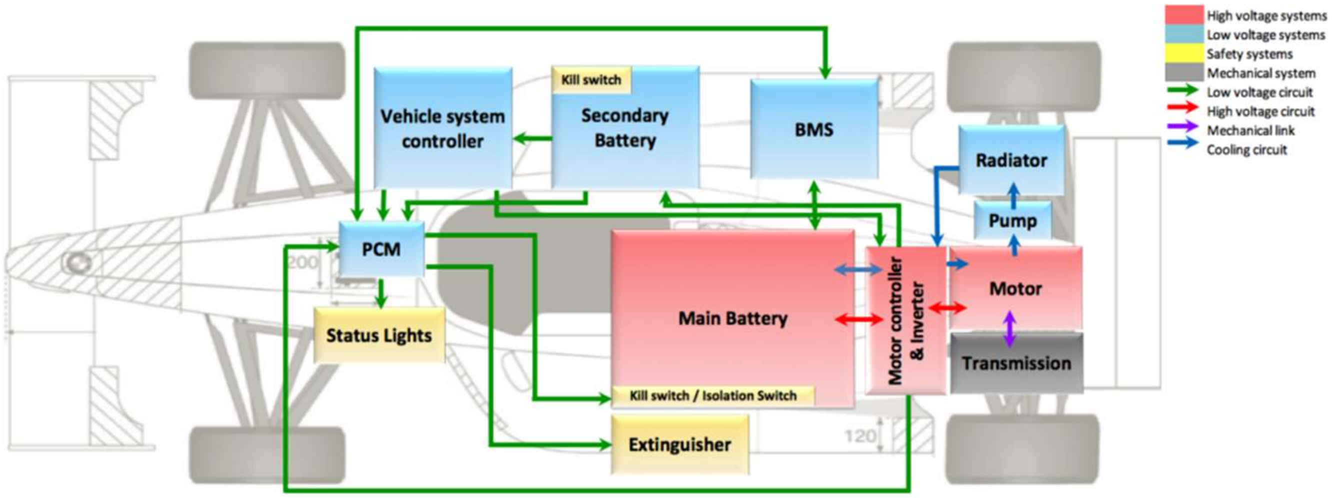


- Guides
- Stores
- Transforms/converts
- Modifies
- Combines, Merges
- Separates or divides
- etc

Function Analysis

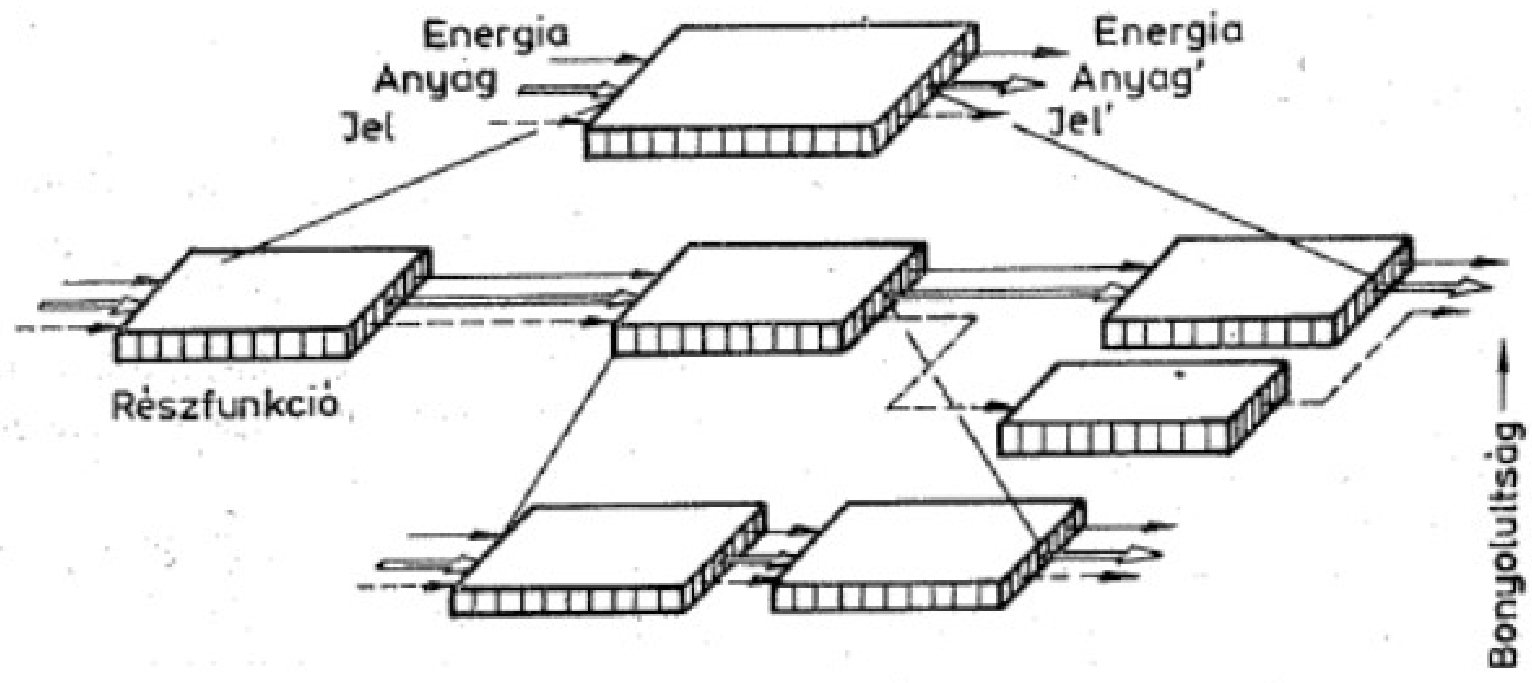
- Electric racecar's sub-functions map



https://www.racecar-engineering.com/tech-explained/how-to-design-a-motorsport-battery-in-7-steps/

Function Analysis

- Function structure



Function Analysis

- Function structure
  - Features
    - Building blocks: elementary functions with general units: material, energy, information
    - Divided:
      - primary functions in the main flow (core operational flow)
      - supporting or auxiliary functions in the subsidiary flow (non critical operations)
  - Creation
    - Building main flow with primary sub-functions
    - Building subsidiary flow
    - Decomposition of more complex sub-functions

Function Analysis

- Function structure
  - Alternatives by
    - logically rearranging the order of individual sub-functions,
    - separating or combining functions,
    - omitting sub-functions,
    - expanding functions,
    - or altering the system boundaries.
  - The variants of the functional structure must be reviewed in every case from the perspective of logical compatibility.



Function Analysis

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How can we improve the steering responsiveness of an all-wheel-drive race car?

Function Analysis

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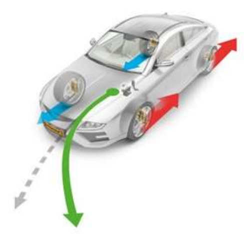
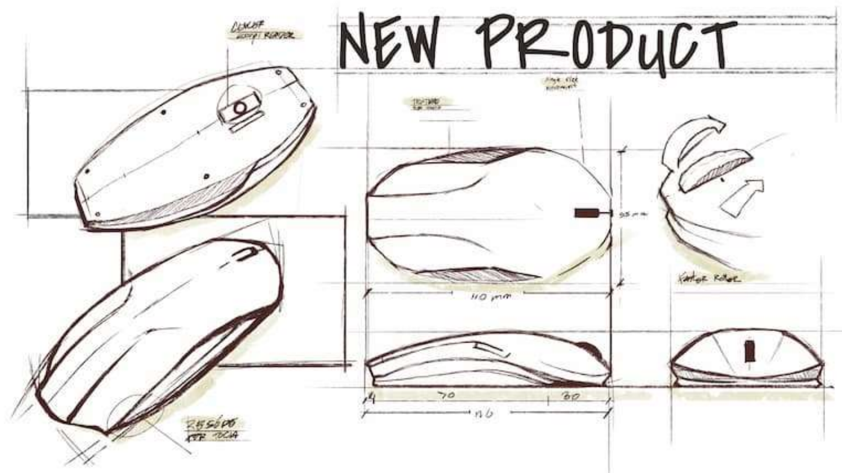
How can we improve the steering responsiveness of an all-wheel-drive race car? Torque vectoring



Concept Generation

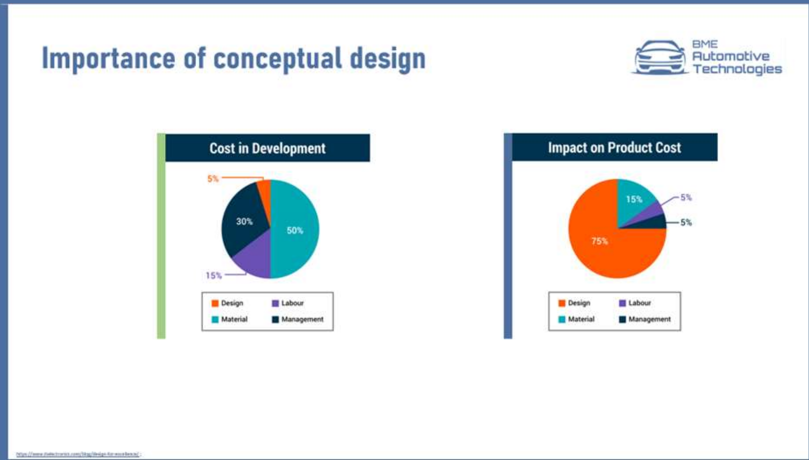
- After function analysis and function structure(s)
  - Morphological matrix
  - Developoment of concepts (Sketches, CAD modeling, Prototyping)
    - Nr 1, 2, 3…
  - Decision



https://fractory.com/product-design-concept-generation/

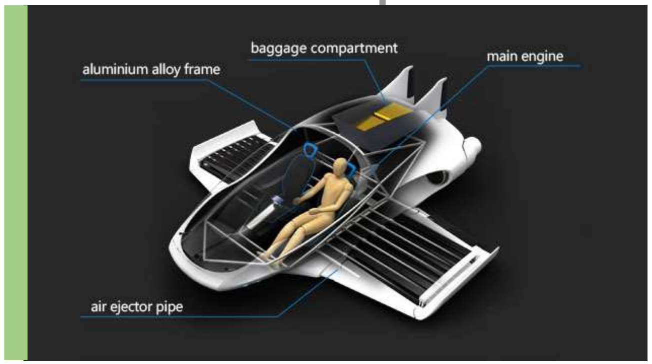
Concept Generation

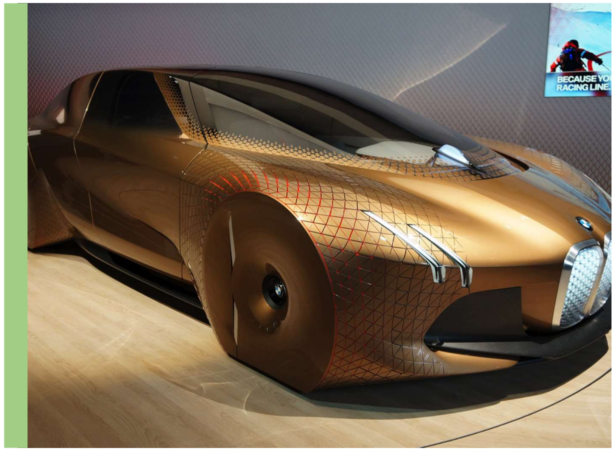
- Idea, plan, perspective
- Starting point: We simplify the task for essential problems.
- Goal: Preparation for design planning.
- Looking for
  - Working principles
  - Recognize essential problems
  - Evaluation from technical and economic aspect
- Laying the foundations.

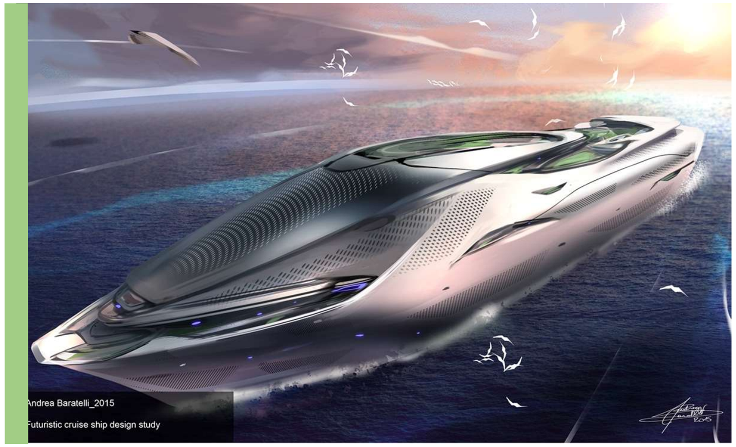


Concept Generation

- Vehicle concepts



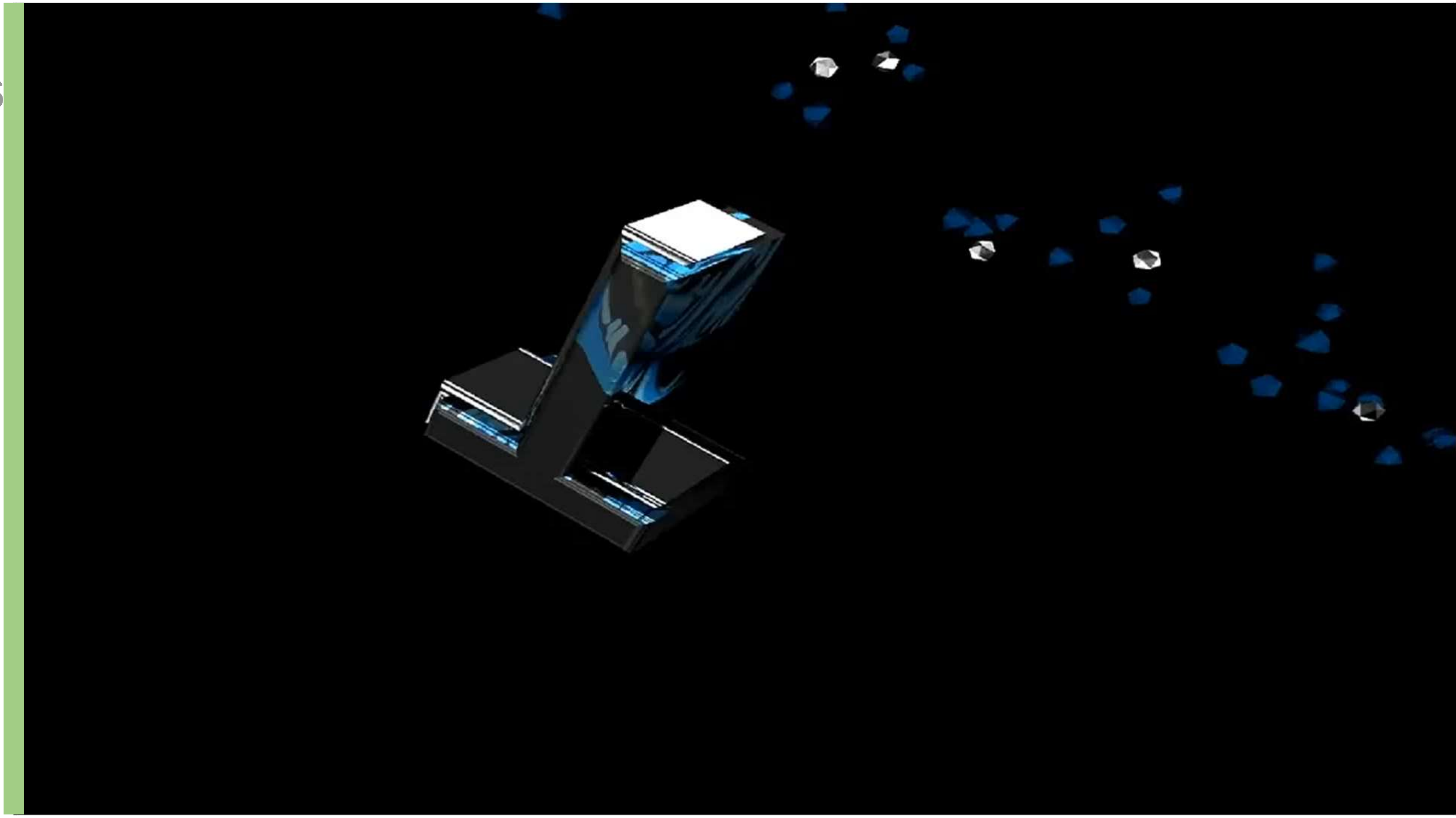




https://theinspirationgrid.com/futuristic-vehicle-concepts-by-roman-dolzhenko/; https://www.theverge.com/2016/6/17/11952334/bmw-vision-next-100-concept-car-photos; https://www.carmagazine.co.uk/car-news/motor-shows-events/detroit/2017/volkswagen-id-buzz-concept-revealed-vws-electric-push-continues-at-detroit-2017-pictures-details/; https://www.behance.net/gallery/28211367/Concept-cruise-ship;

Concept Generation

- Vehicle concepts



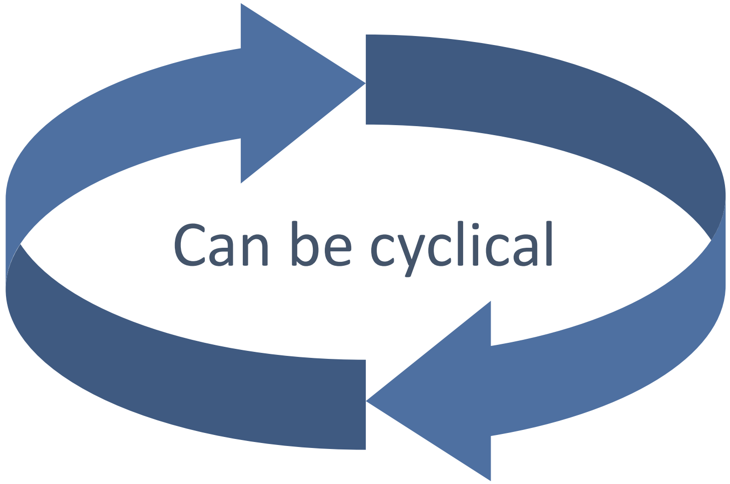
Concept Generation

- Disregard of wishes.
- The omission of expectations (requ., specs.) that do not directly affect functions and conditions.
- Formulation of essential requirements, conditions, and data in the form of short, concise statements.
- Generalization of statements, specifying the input and output quantities that define the function(s).

- Formulating the problem as a function, independent of the solution, wherever possible.

Concept Generation

1. Preparation of the requirements list, data provision for concept development
2. Abstraction to recognize the essence of the problem
3. Establishment of the functional structure: overall function, sub-functions, elementary functions
4. Search for the solution principle required to fulfill sub-functions and elementary functions
5. Combination of solution principles to fulfill the overall function
6. Selection of the appropriate combination
7. Concrete development of concept variants
8. Evaluation based on technical and economic criteria
9. Definition of the concept, data provision for design planning



Concept Generation

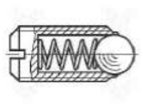
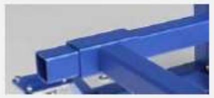
4. Search for the solution principle required to fulfill sub-functions and elementary functions

5. Combination of solution principles to fulfill the overall function

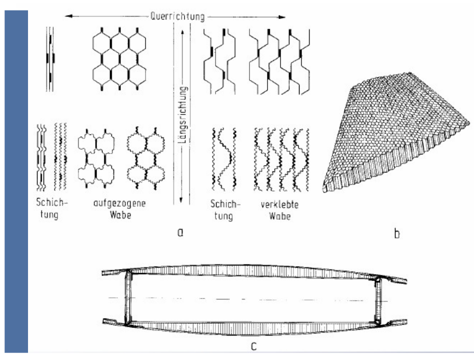
- Tool: Morphological matrix (Recommendation)

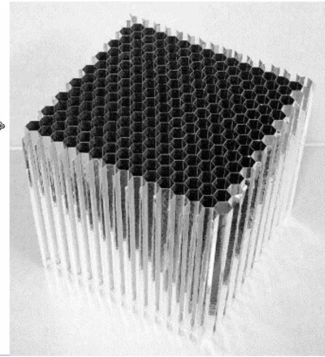
Concept Generation

- Morphological matrix

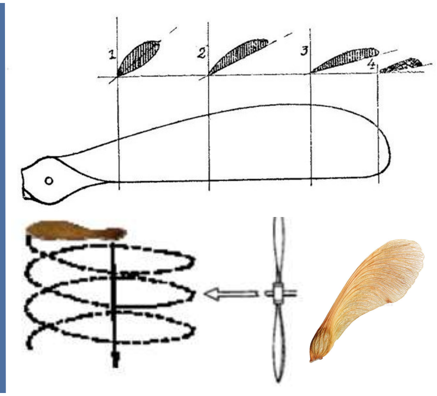
	Funkciók	Megoldások				
		1	2	3	4	5
1	Emelő egység mozgatás	 kerék	 görgő	 sín		
2	**Karosszéria rögzítése a emelőszerkezethez**	 csavar	 csapos rögzítés	 morze kúp	 tokmányba befogás	
3	Emelés	 hidraulikus mh.	 pneumatikus mh.	 menetes orsó	 fogasléc	 drótkötél+csiga
4	**Emelési magasság biztosítása**	 csap	 reteszelés	 önzárás		
5	Karosszéria mozgatása forgástengelyhez képest	 hidraulikus mh.	 pneumatikus mh.	 menetes orsó	 fogasléc	 zártszelvény csúszka

Concept Generation





- Looking for solutions
  - Traditional
    - Literature, Benchmarking, Patent research, Questionnaires or checklists, Systematic negation, Analysis of natural systems, Analogies
  - Intuitive
    - Brainstorming, creative problem-solving, 635 method, Philips 66, NCM-SCM, Delphi-method
  - Discursive
    - Function alaysis, Physics-mathematics principles, Morphological matrix, Design catalogs, TRIZ, Decision matrix



Concept Generation

Decision matrix

- **Procedure of setup:**
  1. Definition of criteria (Product lifecycle, specification, etc.)
  2. Weighting of criteria
  3. Evaluation of conceptual variants based on the criteria
  4. Iteration
  5. Decision-making

		Design #1		Design #2		Design #3		Design #4		Design #5	
Criteria	Weight	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Cost	3	3	9	3	9	1	3	1	3	1	3
Mass	2	3	6	3	6	2	4	1	2	3	6
Durability	1	2	2	1	1	3	3	2	2	2	2
Total			**17**		**16**		**10**		**7**		**11**

Score = Weight × Rating

https://www.researchgate.net/figure/6-Design-decision-matrix_tbl8_282656165;

Concept Generation

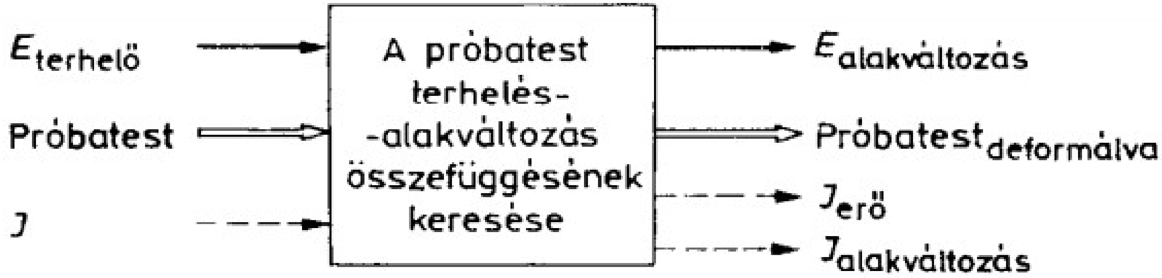
Decision matrix

Vázlatok/ Szempontok	hatékonyság		tömeg		költség		szerelhetőség		összegezve
	érték (1-5)	súlyozott érték	érték (1-5)	súlyozott érték	érték (1-5)	súlyozott érték	érték (1-5)	súlyozott érték	
I.	5	25	2	6	1	2	2	6	39
II.	4	20	4	12	3	6	3	9	47
III.	1	5	3	9	4	8	5	15	37
IV.	4	20	4	12	1	2	2	6	40
V.	4	20	4	12	2	4	2	6	42
súly (1-5)	5		3		2		3		

4. táblázat. Értékelő táblázat

Case studies and examples

- Function structure – Tensile testing machine



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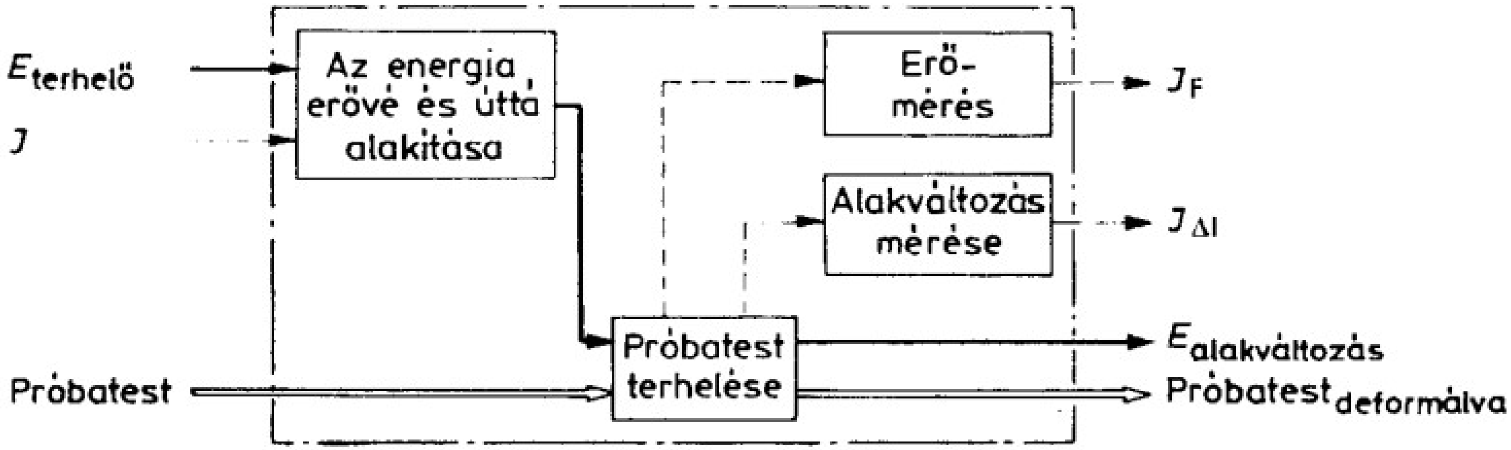
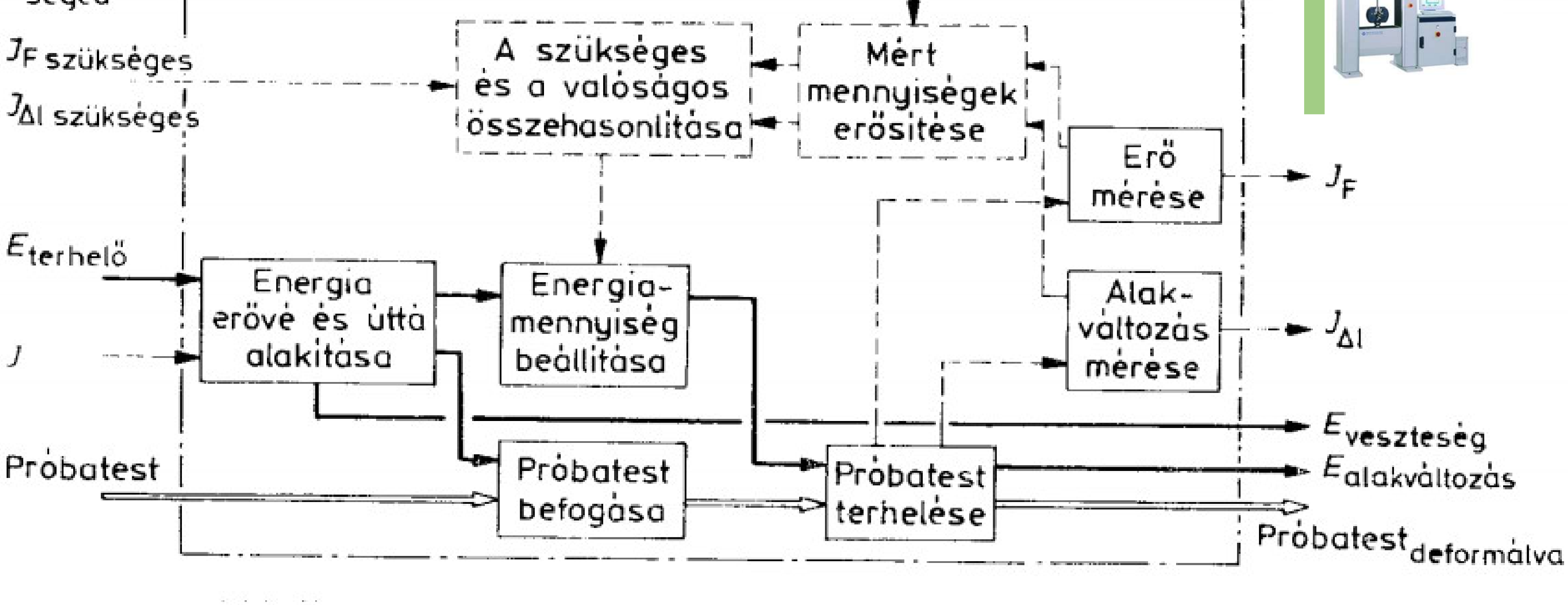


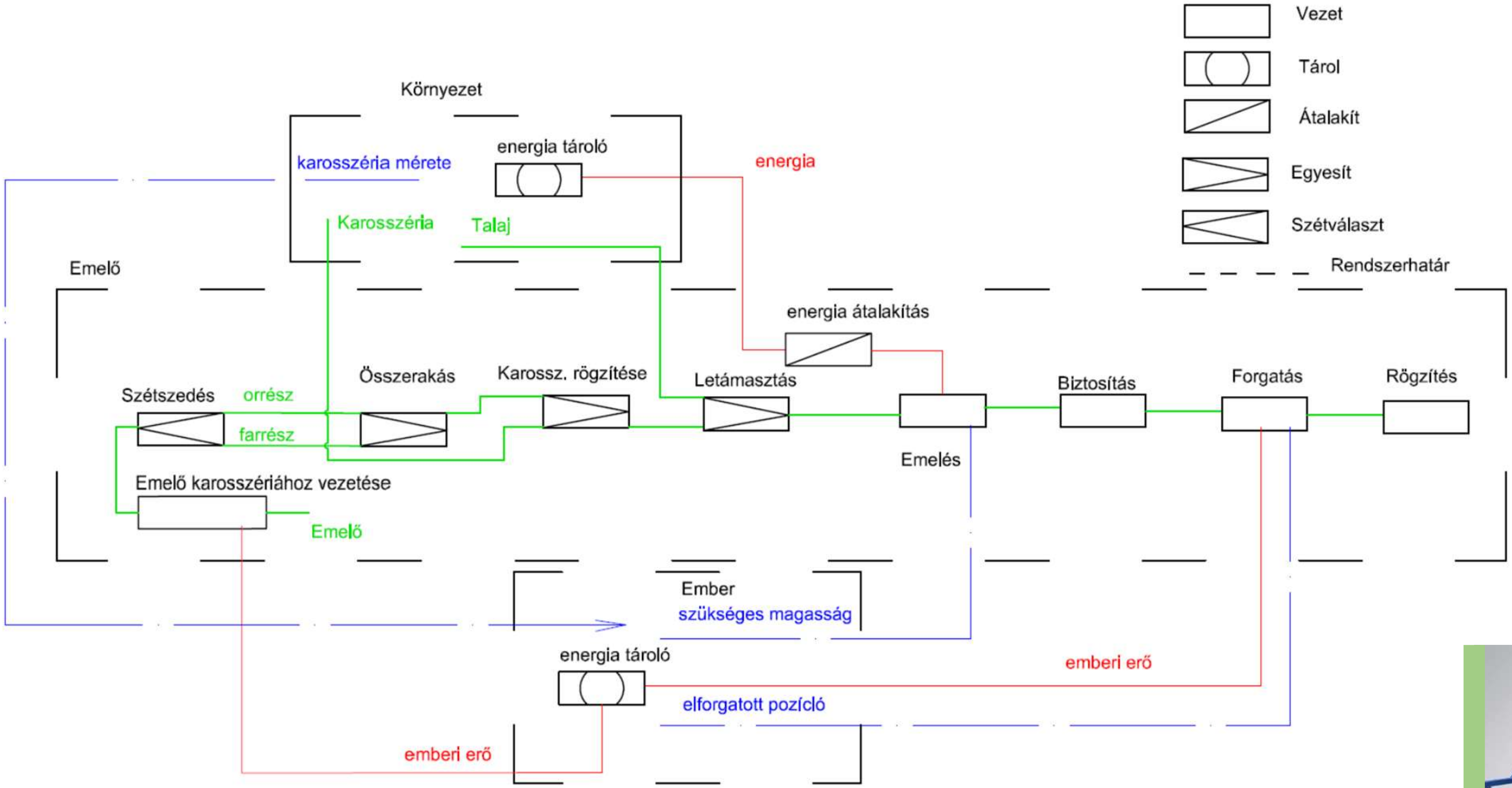
Case studies and examples

- Function structure - Tensile testing machine



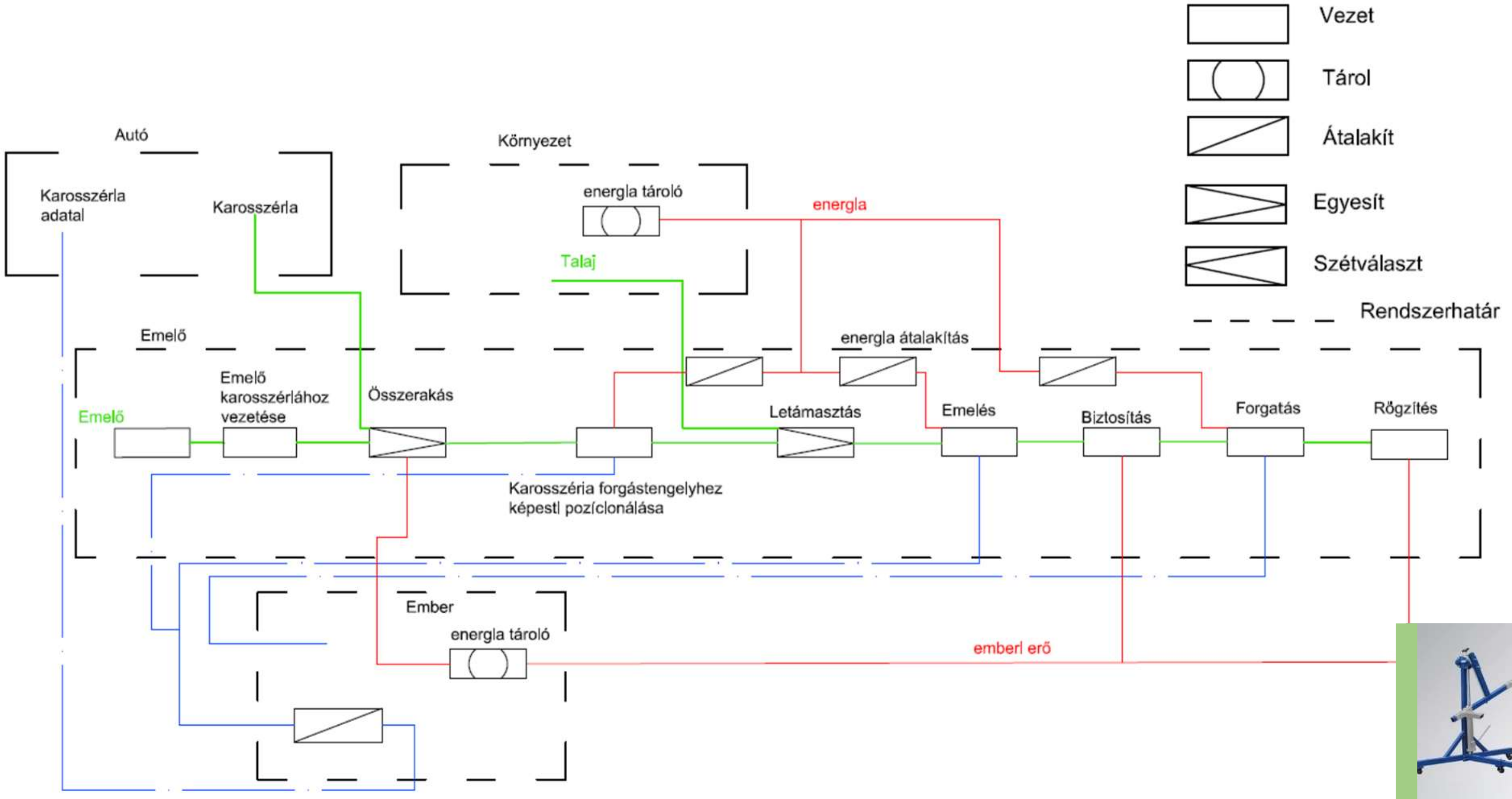
Case studies and examples

- Function structure – Car chassis rotating stand



Case studies and examples

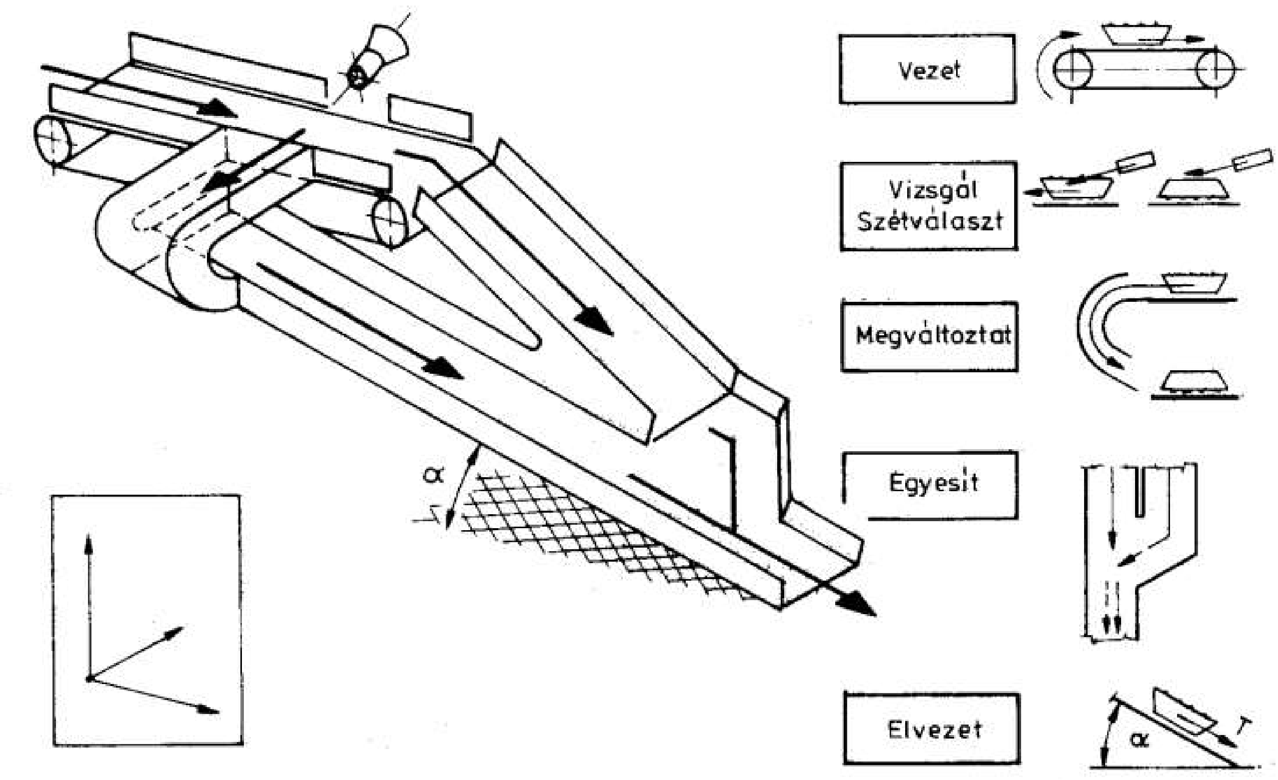
• Function structure – Car chassis rotating stand



Case studies and examples

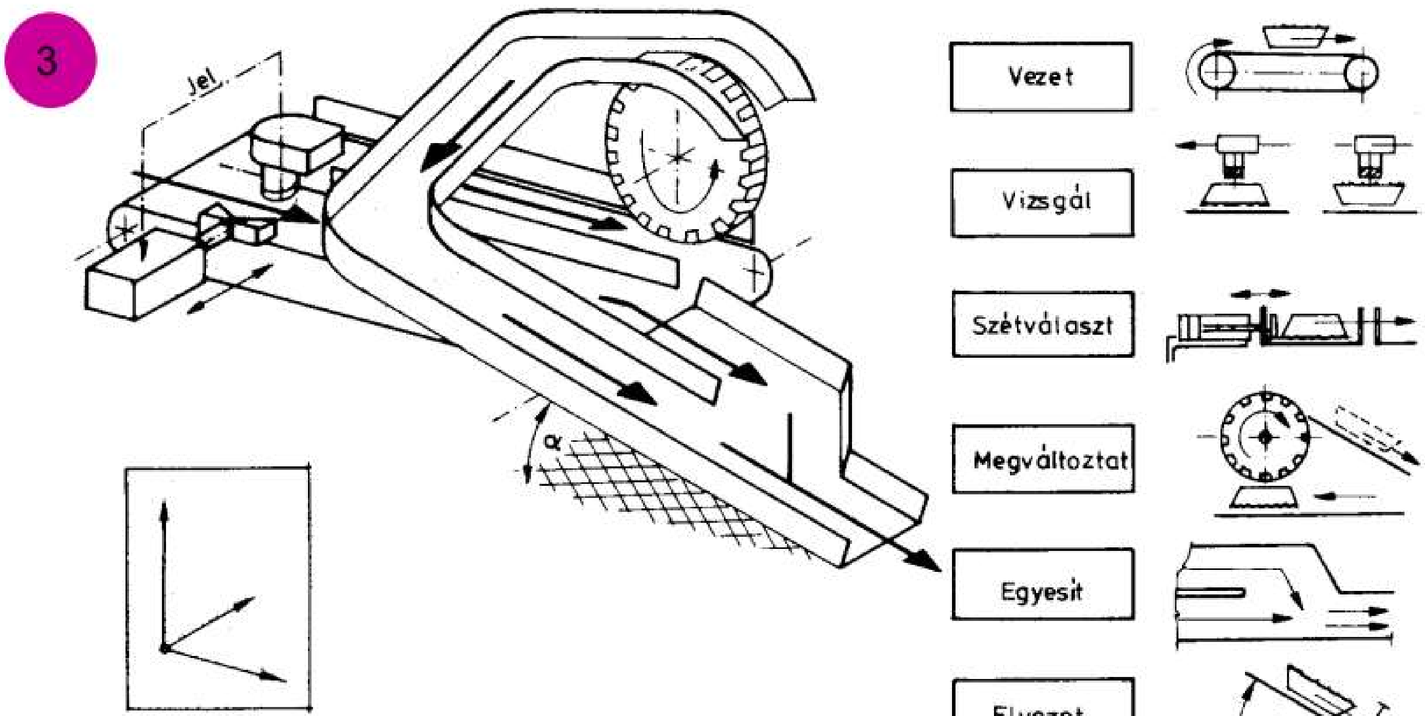
- Theoretical solution outline for a parts organizer and dispenser

3



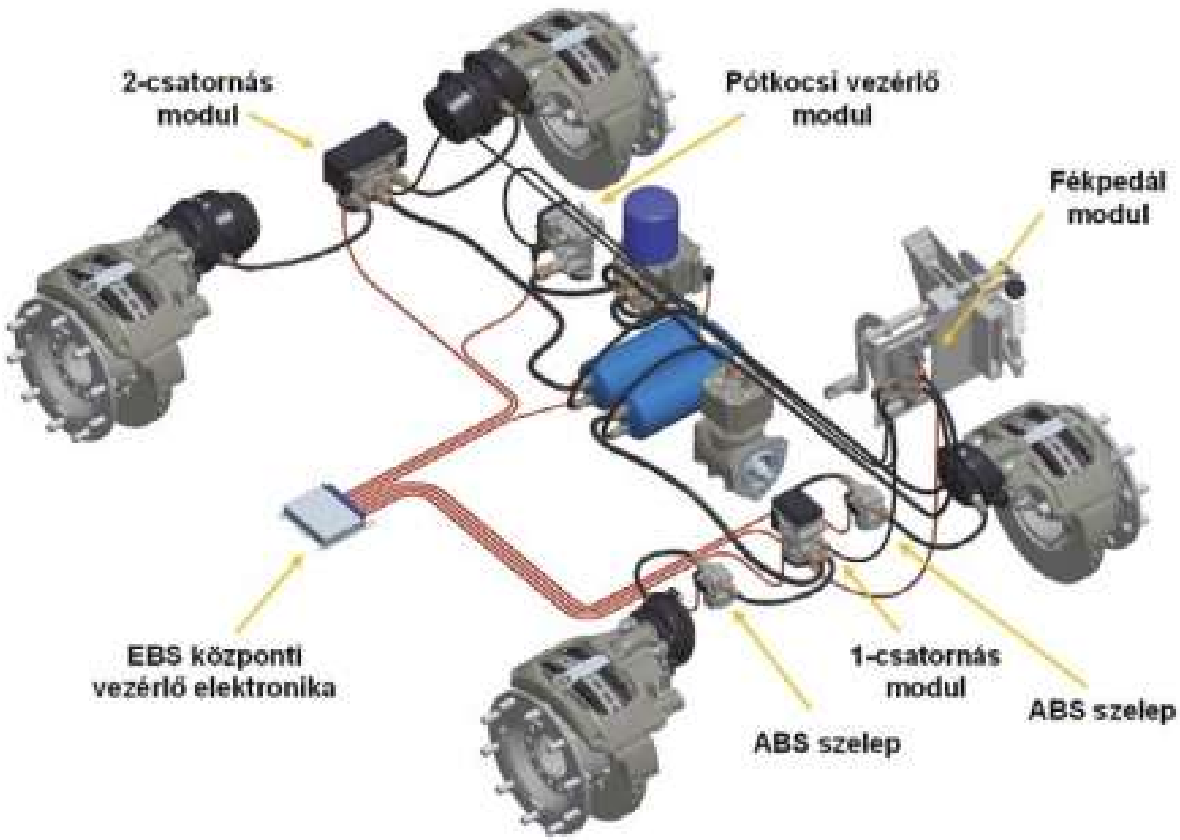
Case studies and examples

- Theoretical solution outline for a parts organizer and dispenser



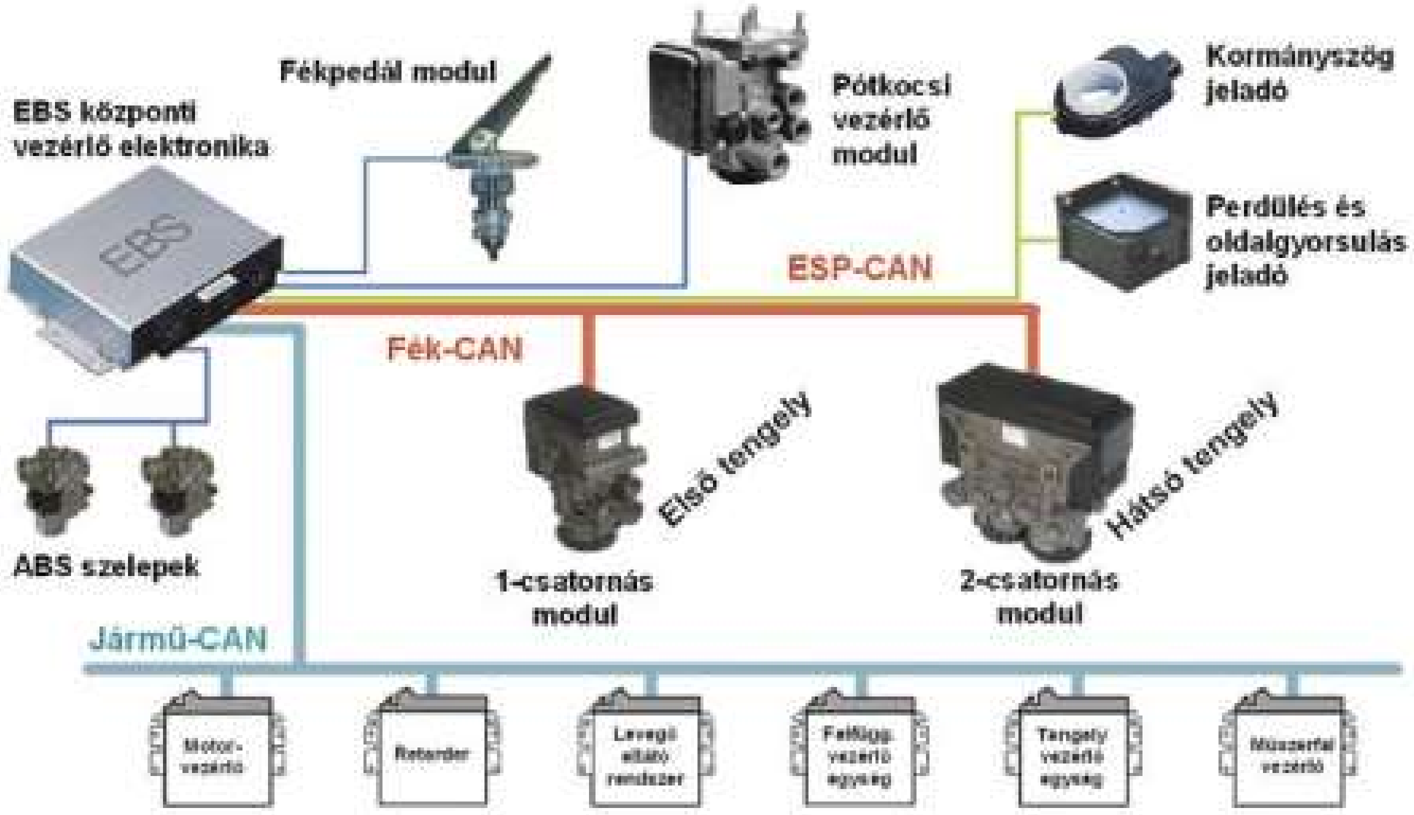
Case studies and examples

- EBS



Case studies and examples

- EBS



Q & A

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- Main objective?
- Starting point-ending point?
- Complex parts?
- Less relevant part(s), could be omitted part(s)?
- Most useful part(s)?

Closing

- Bibliography

  - See bottom of slides
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- Literature

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Thank you for your attention!