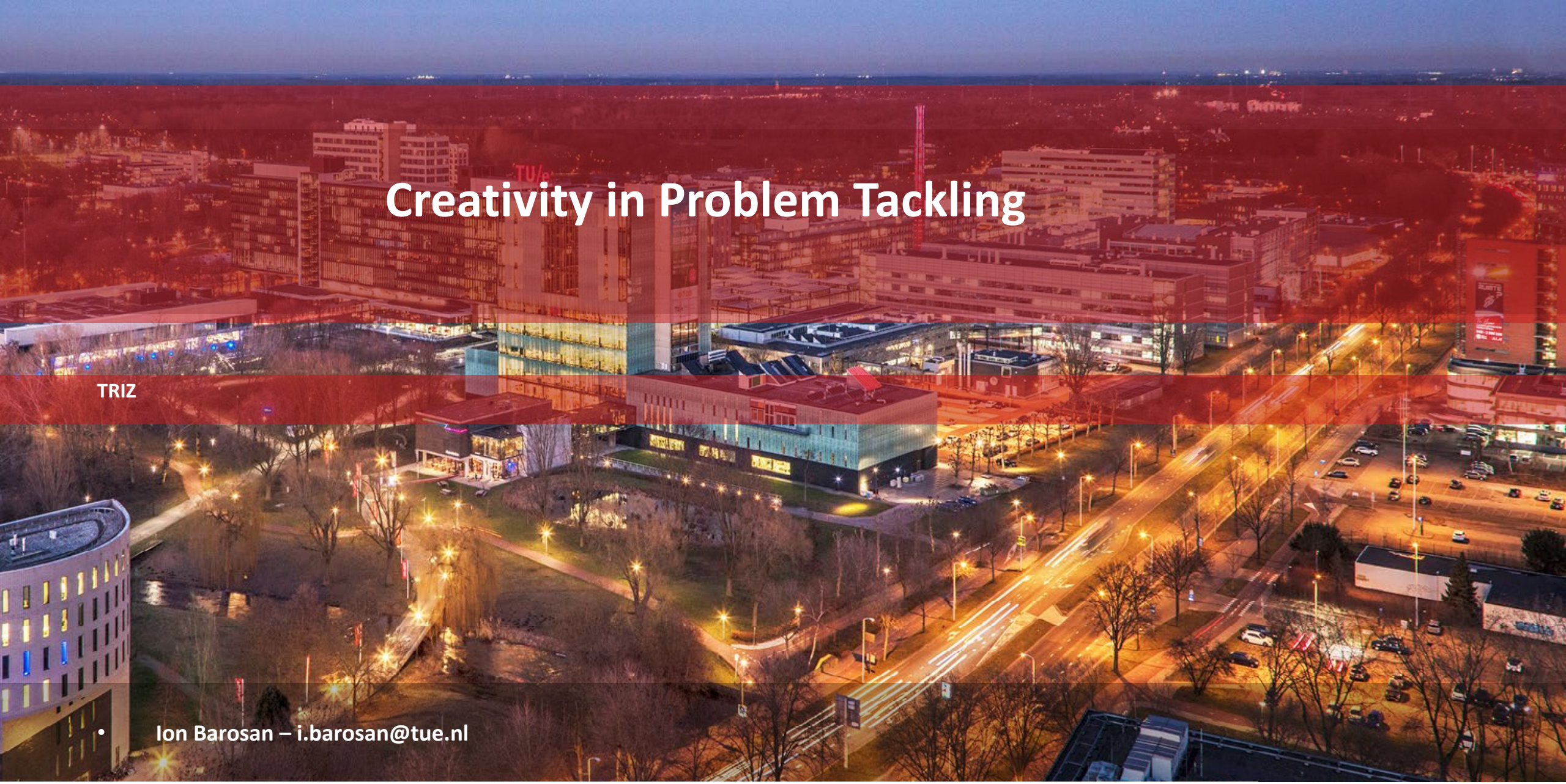


Creativity in Problem Tackling

TRIZ

- Ion Barosan – i.barosan@tue.nl
- Mathematics and Computer Science – SET

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Content

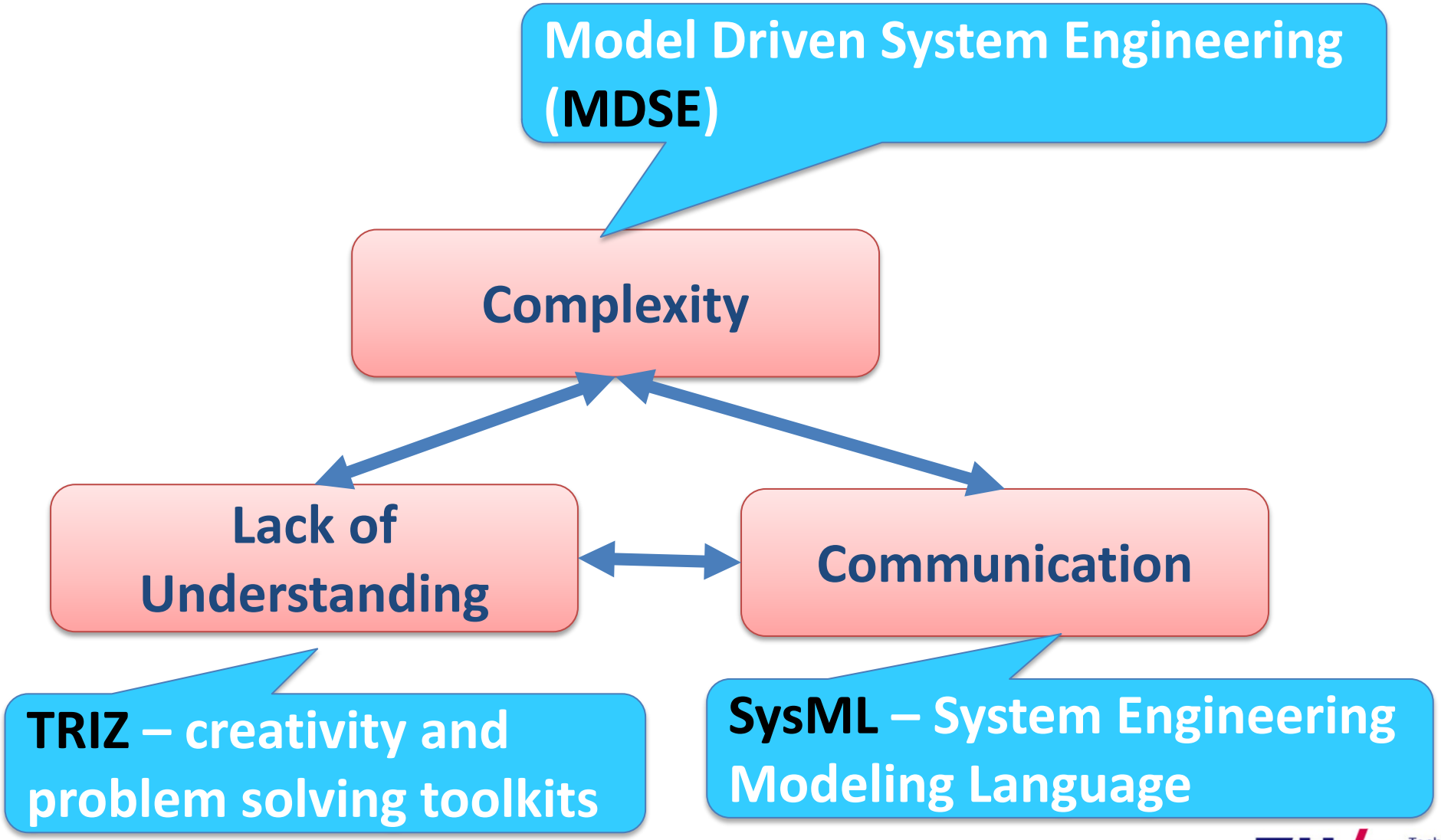
Creativity

1. TRIZ
2. TRIZ Example – Car
3. TRIZ Example –Air Bag
4. TRIZ – 40 Principles

1

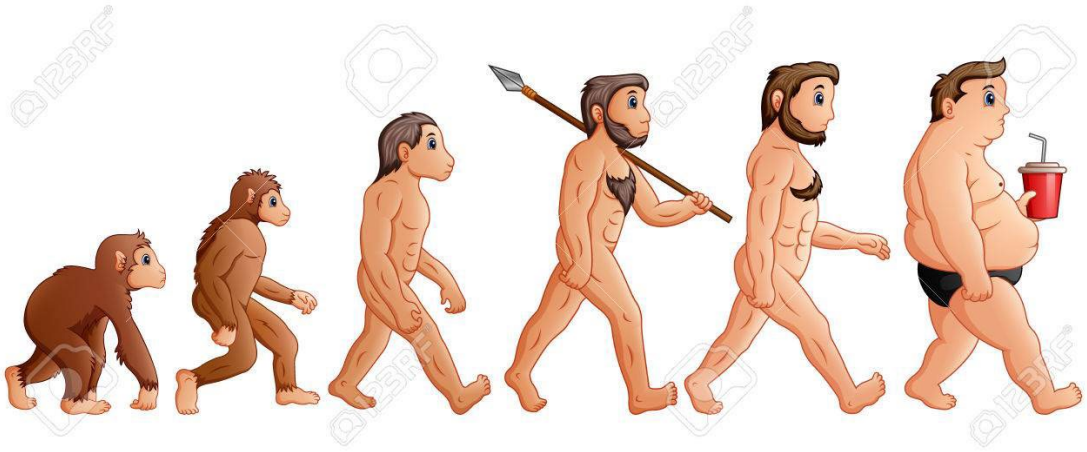
TRIZ

How to tackle the “Three Angels”



Invention of Civilization[1/3]

- **We assume that today the productive age of an individual is up to 40 years**
- **Of 1000 generations in the last 40,000 years :**
  - *more than **800** generations lived without **artificial shelters in woods and caves;***
  - *only **120** generations have known and used **the wheel;***
  - *about **55** generations have known and used the **Archimedes' law;***
  - *about **40** generations have used **windmills** and **watermills;***
  - *about **20** generations have known and used **timepieces;***
  - *about **10** generations have known **printing;***



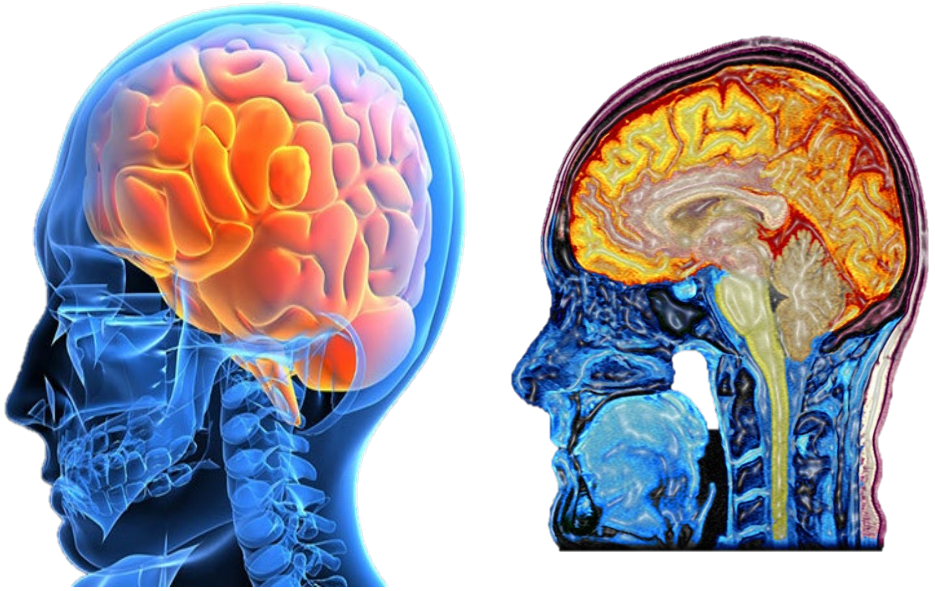
Invention of Civilization[3/3]

- **Of 1000 generations in the last 40,000 years:**
  - **only today's generation** has travelled in **outer space**, has used **atomic energy**, **PCs** and **notebooks**, and uses **artificial satellites** to transmit **audio**, **video** and **other information around the globe.**

- **90 % of the knowledge and all material values that have been arisen in the history of humanity were developed in the 20th century!**

Human Brain[1/3]

- **As a biological object, the human brain has not changed** in the last decades, not in many thousands of years *!)*
- **The organization** and apparently the **working principles** of the brain **are the same** as they were, say, 50,000 years ago.



Human Brain[2/3]

- **The purely biological** over-capacity of the brain **does not lead to quality thinking**:
  - *explains why the number of really valuable inventions does not exceed 1 % of the total number of patents!*
- **Quality thinking** can change in many ways and depends on **the quality of learning and the subjects learned**.
- **Modern technology** and the subjects learned by individuals ***are not without essential faults***.

Where do good ideas come from?[1/2]

- **Genrikh Saulovich Altshuller** (1926-1998) told the people:
  - **the entire civilized world that it cannot think**
    - ***This means that people waste their intellectual potential because of poorly organized thinking***
    - *they also don't suspect that they think ineffectively!*
  - **today, just like thousands of years ago, the method of *try and error* is the basis of thinking.**

Where do good ideas come from?[2/2]

- **The method of *try and error* is the basis of thinking:**
  - is an unstructured guess for some kind of solution. Very ***few of these ideas are successful***, and ***most of these are abandoned later.***

- ***Wouldn't it be more logical to learn from success?!***

- Even better to **condense the experience** gathered from **the best solutions into concrete rules** and to **develop a methodology** with complete models or even as a practical theory.

What is TRIZ ?[1/3]

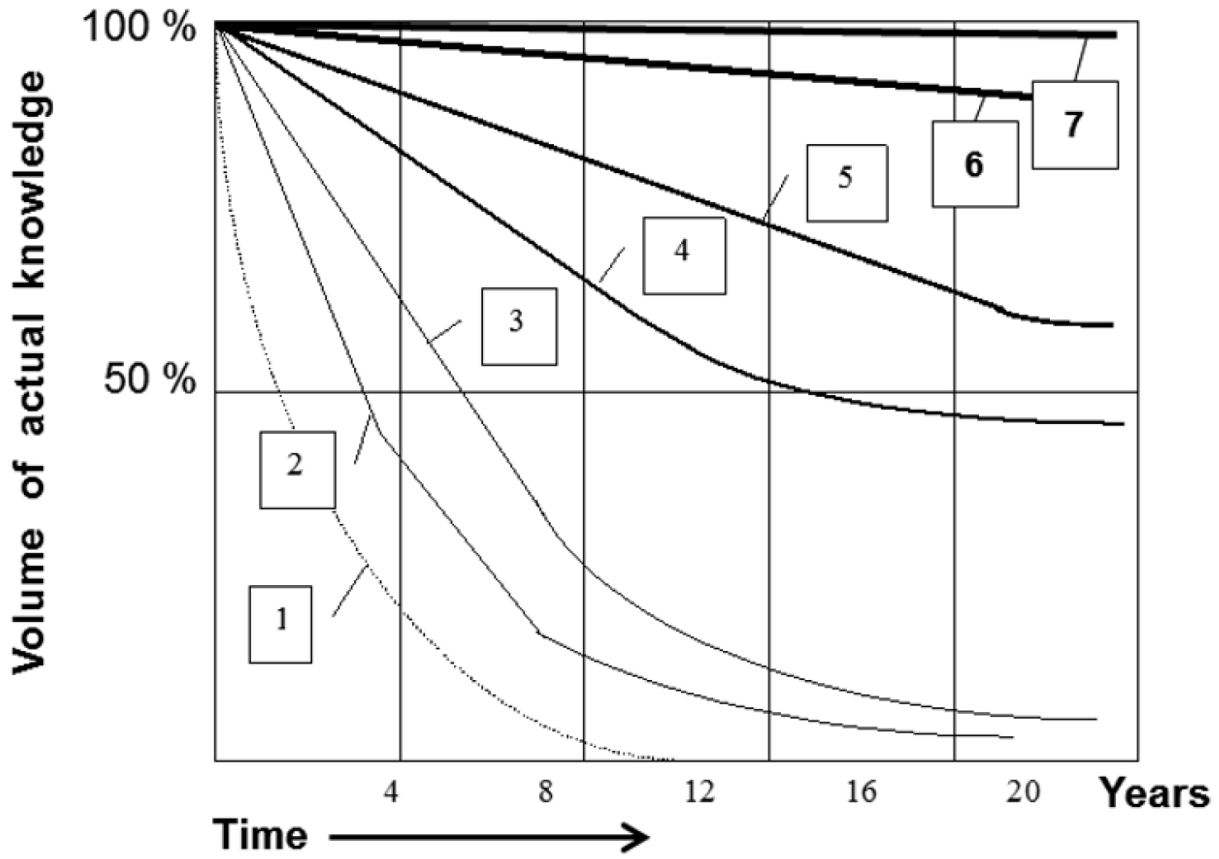
- **A unique, rigorous and powerful toolkit:**
  - *guides engineers to understand and solve their problems by accessing the immense treasure of past engineering and scientific knowledge.*
- **TRIZ helps us** find the surprisingly **few relevant and practical answers** to our real problems.

- **TRIZ summarizes** *of all the conceptual answers to engineering and scientific problems.*

The Effectiveness of Our Skills

- Experts have established that in the modern world some ***knowledge changes very fast***, e.g., computer technologies and software, while other ***knowledge changes slowly, e.g., school knowledge***.

The obsolescence of basic knowledge and skills



Knowledge:

7 – TRIZ
6 – arithmetic
5 – school
4 - university
3 – specialized branch
2 – technology
1 – data processing

(Source: Maschinenmarkt, 25'1995, p.38 – without TRIZ-line)

How difficult is to learn to be Creative?

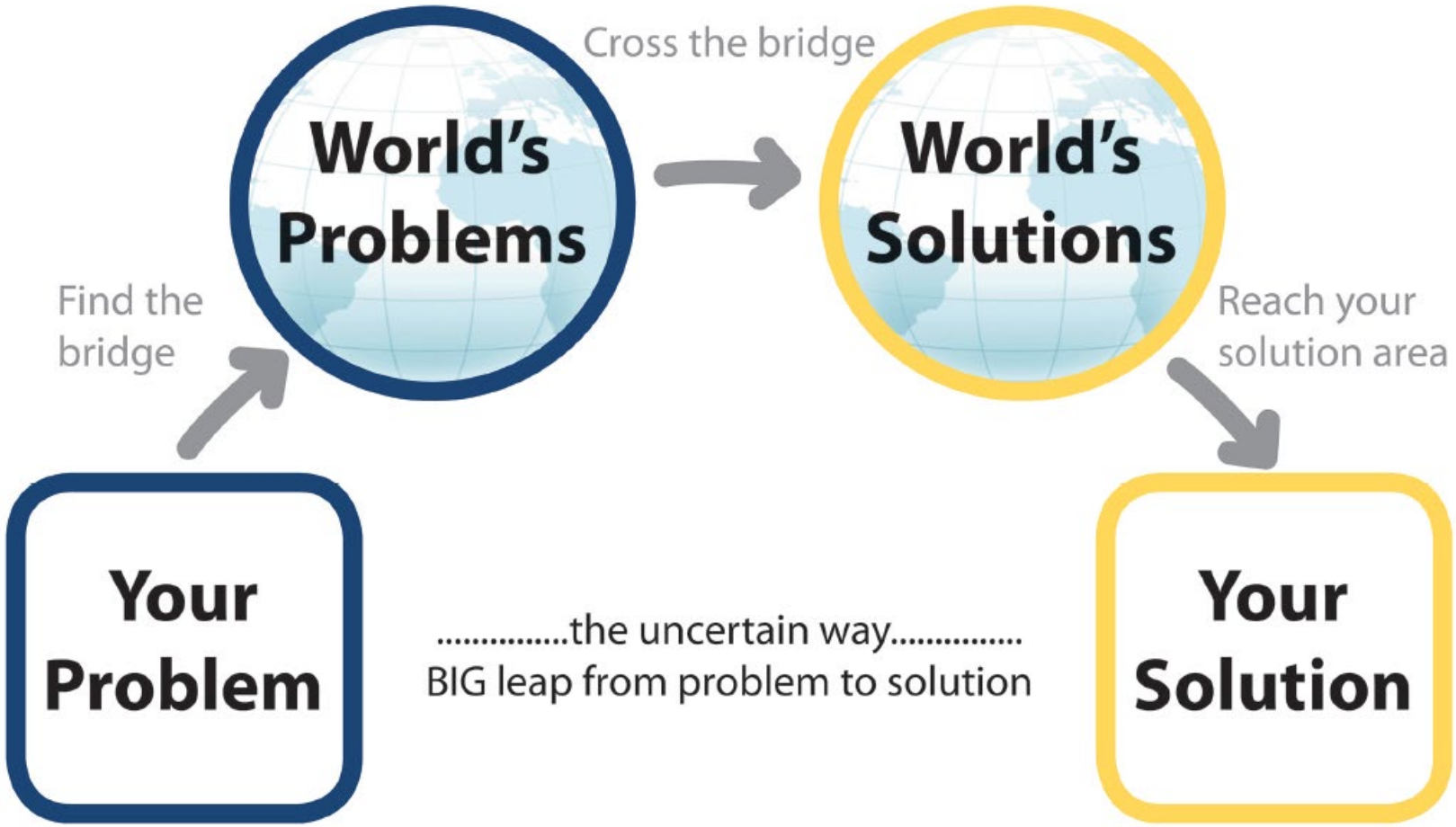
- **Sergey Rakhmaninov:** *If I don't play for one day, I notice that; if I don't play for two days, my family members notice that; if I don't play for three days, everybody notices that!*
  - Now, do not forget that he was a great pianist! This means that even masters need *ongoing training*.

- ***The Philosophy of Invention:***
  - *Indeed, at the decisive moment, when you need to be mobilized and concentrated, it is too late to ask yourself whether you have done everything that you could have done in the period leading up to that moment.*

Miracle of Invention

- The study of the primary (basic and advanced) models is ***absolutely necessary*** to acquire the skills needed to apply these models.
  - *The models are universal and independent from the field of their application, although some of the models are still too "technocratic."*
  - *They can be adapted to any kind of situation or problem.*

TRIZ Problem Solving



Uncovering and Solving Contradictions

We need practice to recognize and uncover technical contradictions

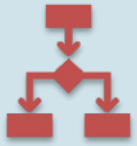
- looking for situations when our solution gives us what we want ***but*** it comes with some bad consequence for some previously good feature or function.

Examples of Technical Contradictions occur everywhere:

- **Digital camera** – we want small pixels (better resolution) ***but*** this gives us increased noise.
- **Cooling fan** – how can we get good airflow, ***but*** without noise?
- **A larger heat** sink dissipates more heat ***but*** is bigger.
- **I enjoy eating** cream cakes ***but*** they are bad for me.

Technical Contradiction

I get something good *but* I then also get something bad.



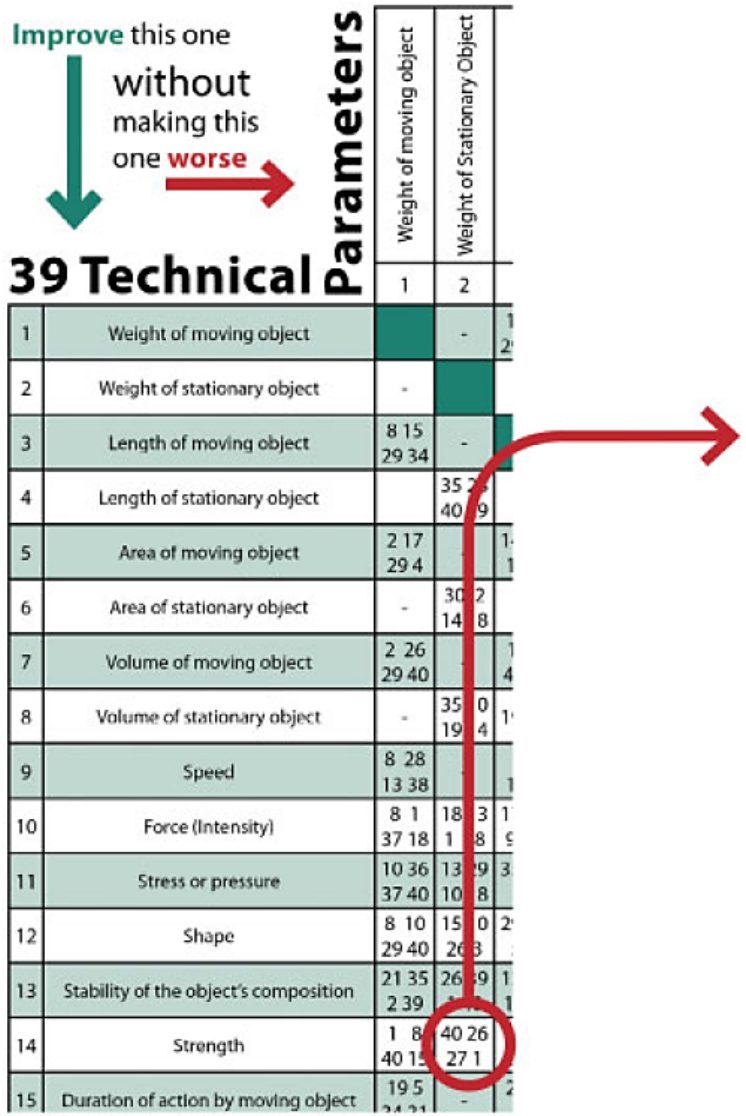
We think of a solution to improve something *but* something else gets worse.

We must choose one solution, technical parameter or feature at the expense of the other ?

without TRIZ we initially assume we can ’ t have both.

we believe that the two features are inevitably linked and that when we improve one, then the other will inevitably get worse in some way.

Solving Technical Contradictions



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2	Weight of stationary object	-	
3	Length of moving object	8 15 29 34	-
4	Length of stationary object		35 40
5	Area of moving object	2 17 29 4	
6	Area of stationary object	-	14
7	Volume of moving object	2 26 29 40	
8	Volume of stationary object	-	19
9	Speed	8 28 13 38	
10	Force (Intensity)	8 1 37 18	18 1
11	Stress or pressure	10 36 37 40	13 10
12	Shape	8 10 29 40	15 26
13	Stability of the object's composition	21 35 2 39	26
14	Strength	1 40 15	40 26 27 1
15	Duration of action by moving object	19 5	-

Solving Technical Contradictions by using the matrix shows us how to break the link and *separate* the two parameters – the Inventive Principles suggest ways of improving/changing one without also affecting the other one or making it worse.

The matrix offers these Inventive Principles **40, 26, 27,**

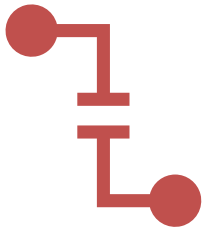
40 – Composite Materials

26 – Copying

27 – Cheap Short-Living Objects

1 – Segmentation

Physical Contradiction



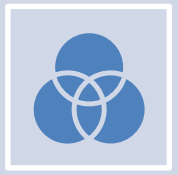
We want opposite solutions – for example, high and low.

Example:

We want a high garden fence for our garden boundary – but we also want a low fence so it doesn ’ t get blown down in high winds.

we have to find a fence that **is *there* for privacy but *not there* for high winds** – and such fences exists and is called a **Hit and Miss**.

How To Solve Physical Contradictions

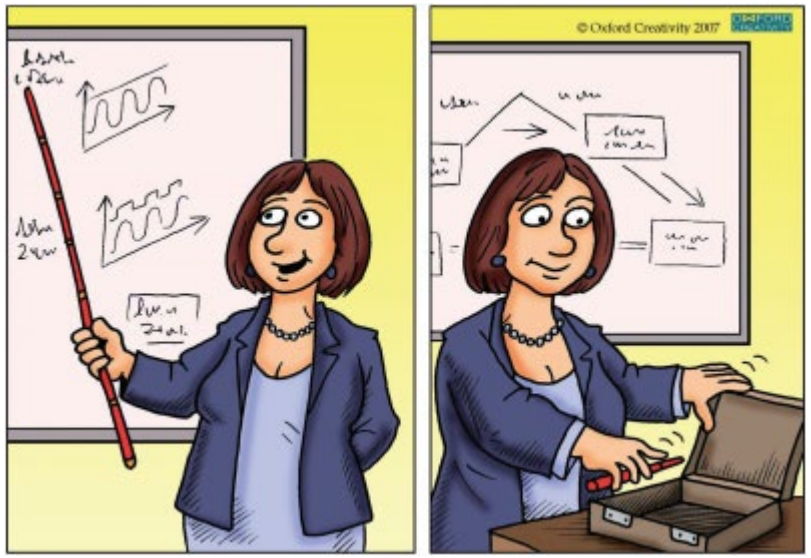


Physical contradictions are solved by **separating the solutions in different ways which gives both solutions**.

We can separate **in time, in space, on condition** or **in scale**.

Separate in Time

- **One solution at one time** (long board pointer)
- **The opposite solution at another time** (short board pointer).



Principle No 7 – Nested Doll

Separate in Time

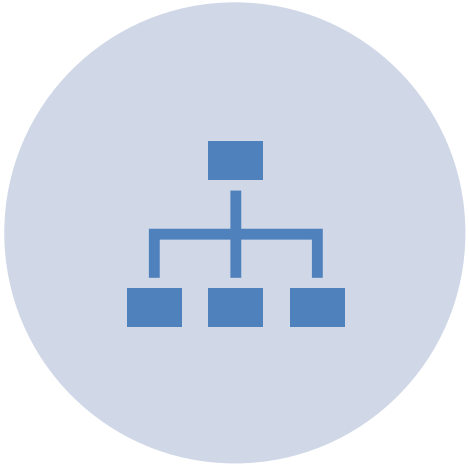
- When we **want systems *there* at one time** – when we want them ***but not there* at another time when we don ’ t.**

Separate in Space

- We have **one solution in one place** (cold outside of coffee cup)
- **The opposite solution in another place** (hot inside cup).

A coffee cup has to be hot AND cold –
at the same time but in different places

The 39 Technical Parameters



EACH MATRIX AXIS IS MADE UP OF **39 TECHNICAL PARAMETERS** WIDELY USED AND **IMPORTANT CHARACTERISTICS OF TECHNICAL SYSTEMS**.

THEY RANGE FROM SIMPLE TO COMPLEX FEATURES AND FUNCTIONS, AND BETWEEN THEM CAN DESCRIBE ANY ENGINEERING CONTRADICTION.

The 39 Technical Parameters

1	Weight of Moving Object	14	Strength	27	Reliability
2	Weight of Stationary Object	15	Duration of Action by Moving Object	28	Measurement Accuracy
3	Length of Moving Object	16	Duration of Action by Stationary Object	29	Manufacturing Precision
4	Length of Stationary Object	17	Temperature	30	Object-Affected Harmful Factors
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6	Area of Stationary Object	19	Use of Energy by Moving Object	32	Ease of Manufacture
7	Volume of Moving Object	20	Use of Energy by Stationary Object	33	Convenience of Use
8	Volume of Stationary Object	21	Power	34	Ease of Repair
9	Speed	22	Loss of Energy	35	Adaptability or versatility
10	Force	23	Loss of Substance	36	Device Complexity
11	Stress or Pressure	24	Loss of Information	37	Difficulty of Detecting and Measuring
12	Shape	25	Loss of Time	38	Extent of Automation
13	Stability of Object's Composition	26	Quantity of Substance	39	Productivity

TRIZ General Solutions

1. Segmentation
2. Extraction, Separation, Removal, Segregation
3. Local Quality
4. Asymmetry
5. Combining, Integration, Merging
6. Universality, Multi-functionality
7. Nesting
8. Counterweight, Levitation
9. Preliminary anti-action, Prior counteraction
10. Prior action
11. Cushion in advance, compensate before
12. Equipotentiality, remove stress
13. Inversion, The other way around
14. Spheroidality, Curvilinearity
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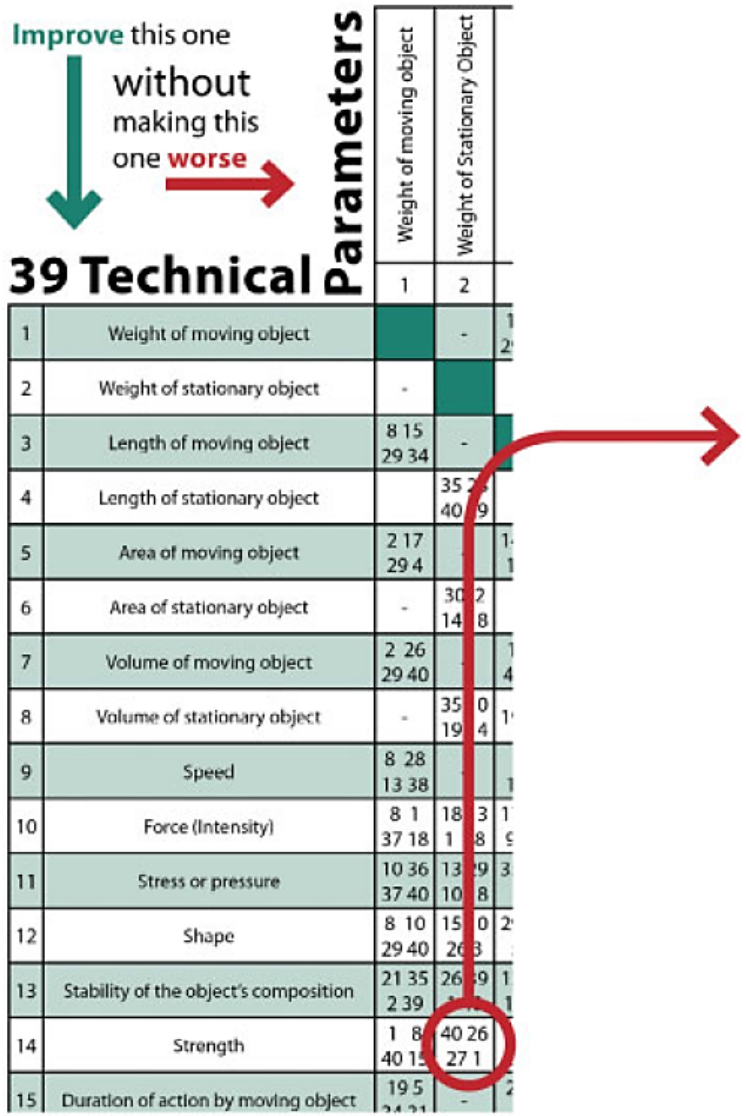
26. Copying
27. Cheap, disposable objects
28. Replacement of a mechanical system with 'fields'
29. Pneumatics or hydraulics:
30. Flexible membranes or thin film
31. Use of porous materials
32. Changing color or optical properties
33. Homogeneity
34. Rejection and regeneration, Discarding and recovering
35. Transformation of the physical and chemical states of an object, parameter change, changing properties
36. Phase transformation
37. Thermal expansion
38. Use strong oxidizers, enriched atmospheres, accelerated oxidation
39. Inert environment or atmosphere
40. Composite materials

Solving Technical Contradictions



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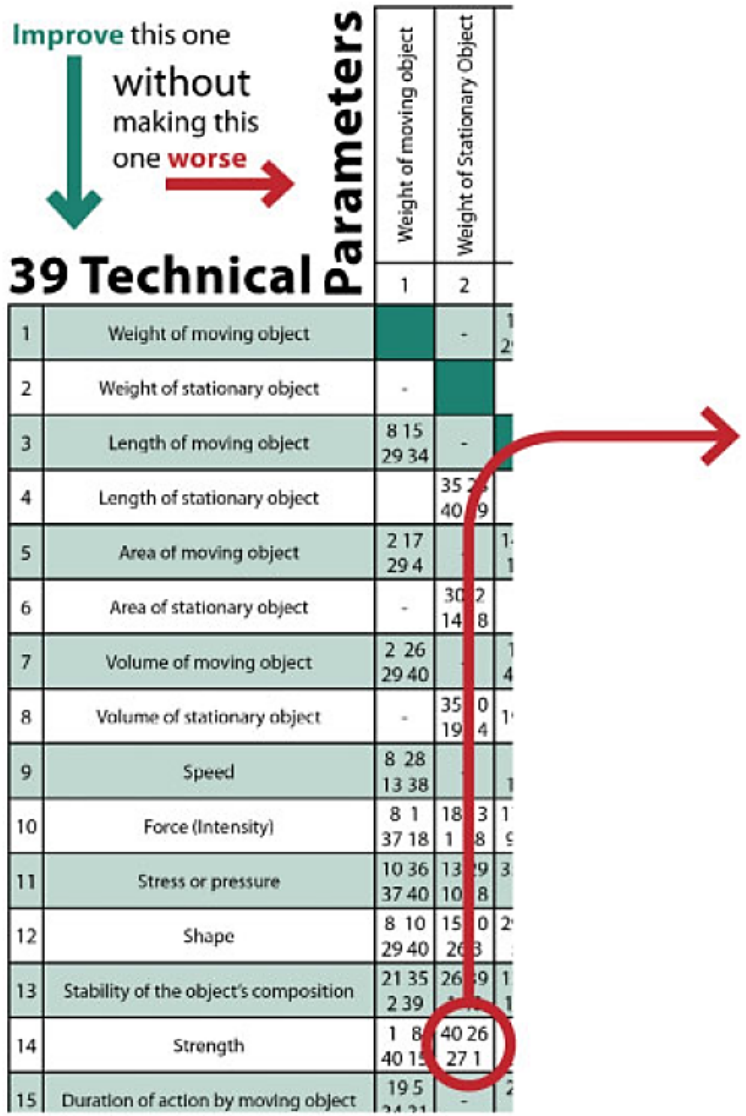

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Classes of TRIZ tools

The tools based on patent analysis and scientific journals

- ✓ 40 Inventive Principles
- ✓ 8 Trends of Technical Evolution
- ✓ TRIZ Effects Database
- ✓ 76 Standard Solutions

The tools developed to help you model your problem conceptually

- ✓ Contradictions
- ✓ Function Analysis
- ✓ X-Factor

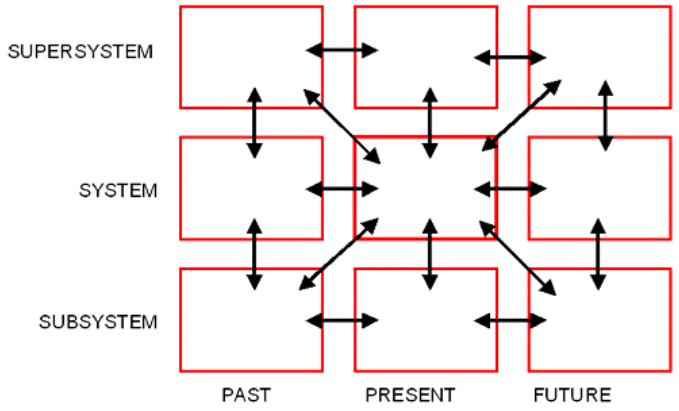
The thinking tools based on modelling thought processes

- ✓ Thinking in Time and Scale
- ✓ Ideal Outcome
- ✓ Resources
- ✓ Size–Time–Cost
- ✓ Smart Little People

Thinking in Time and Scale

Thinking in Time and Scale helps you to explore at what level a problem needs to be tackled.

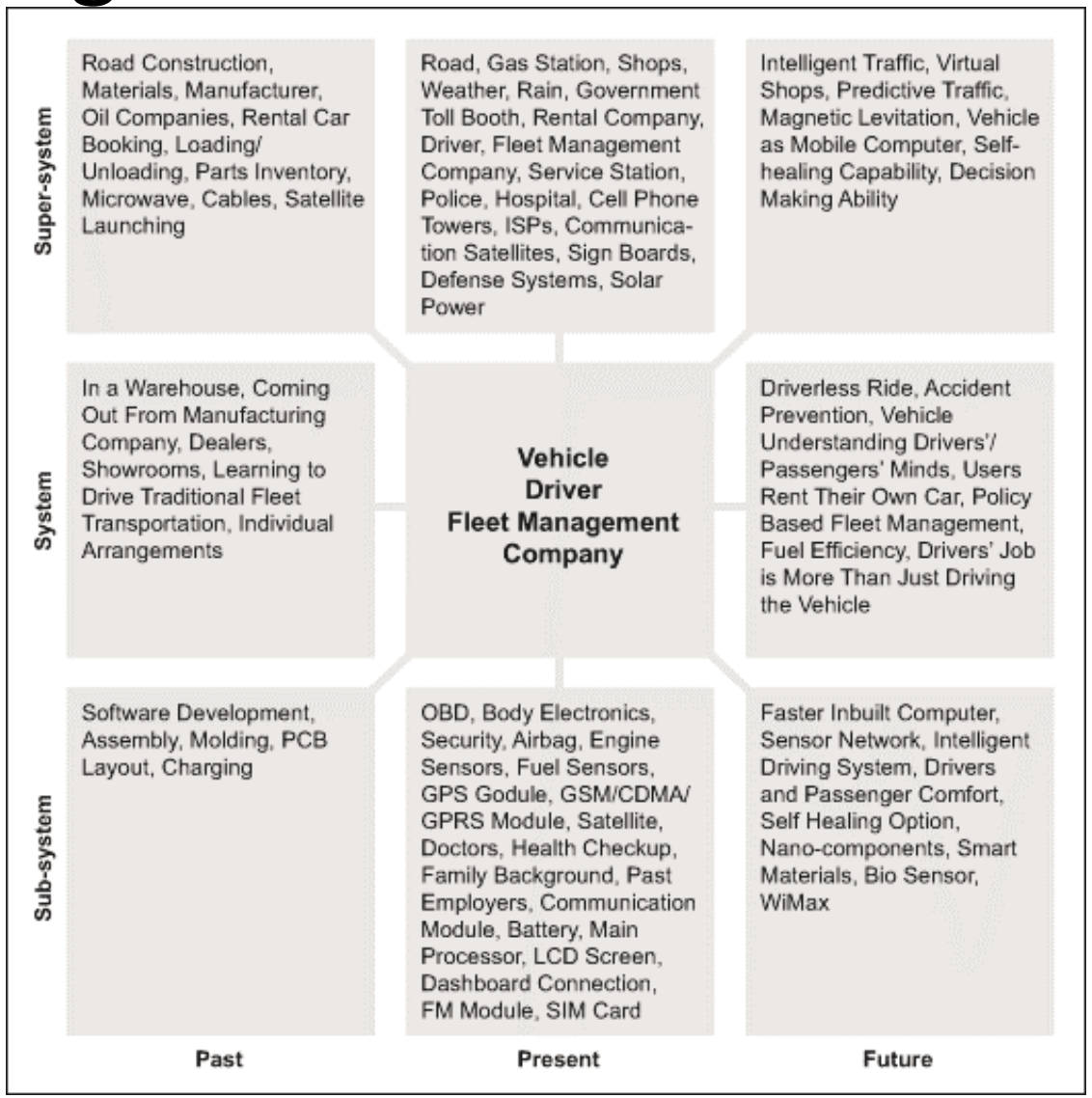
Completing a 9 Box Solution Map helps you find inventive solutions to your problems.



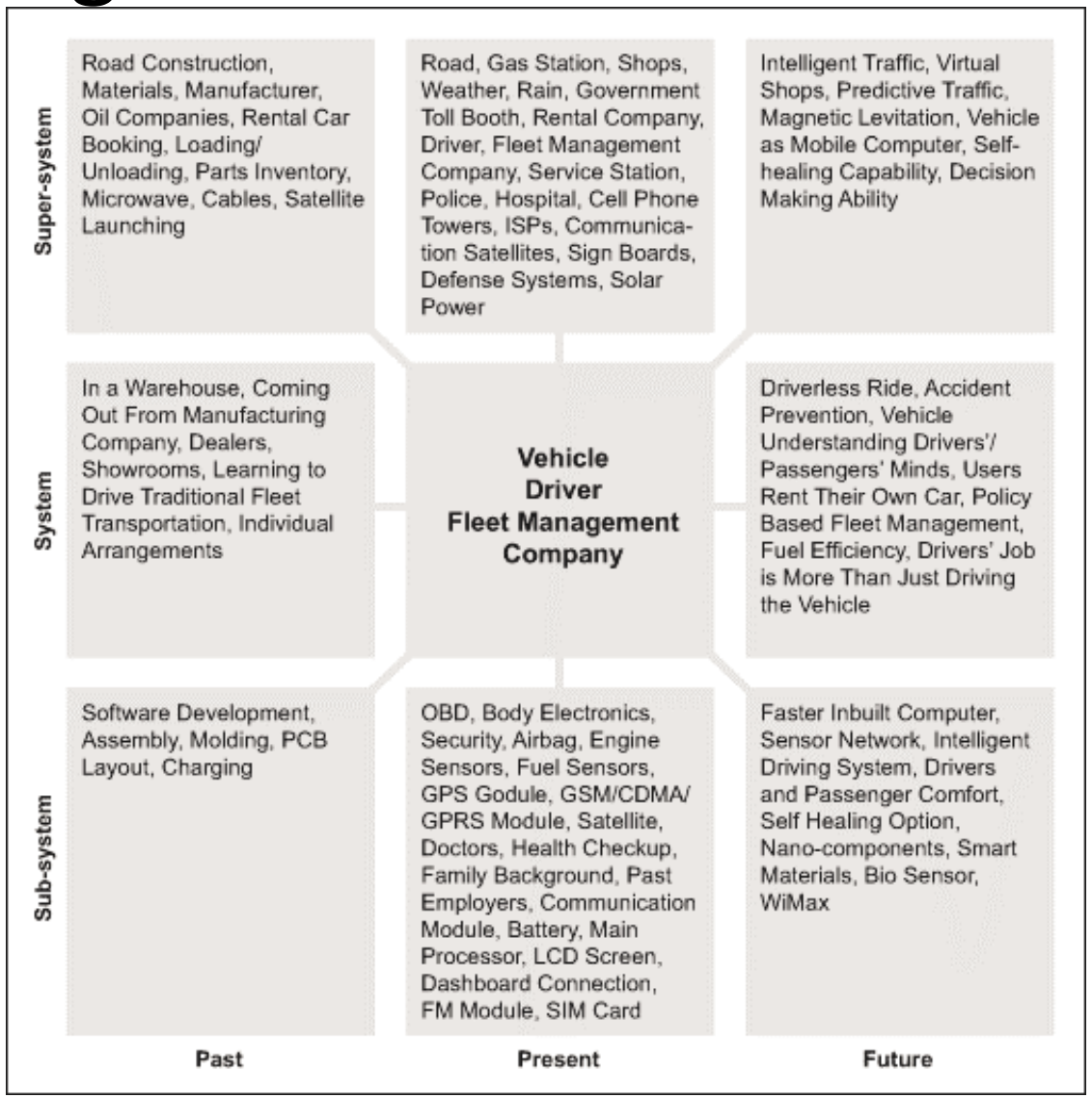
Thinking in Time and Scale helps us:

1. *Widen our field of thinking;*
2. *See the big picture and the detail and the relationship between them;*
3. *Map the significance of time in terms of the history, the process steps, conflicting benefits etc.;*
4. *Realize that there are many valid approaches to solving a problem;*
5. *Remove many constraints in our thinking;*
6. *Communicate the history.*

Thinking Like a Genius – 13 TRIZ Tools



Thinking Like a Genius – 13 TRIZ Tools



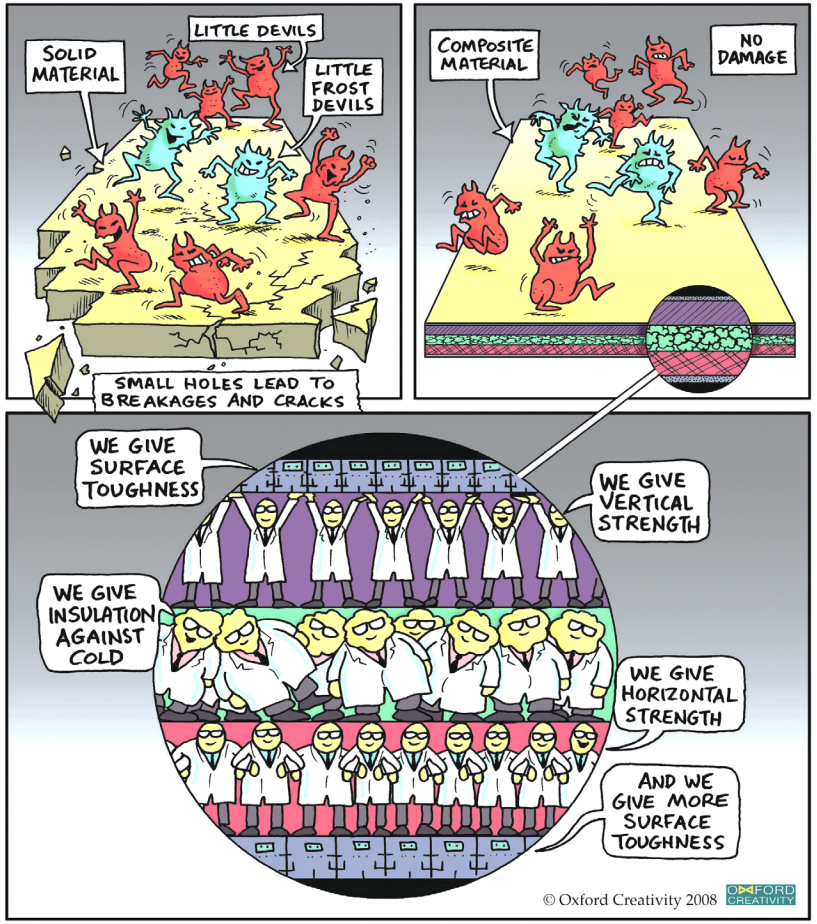
Smart Little People

- **Smart Little People** shows you how to model problems and find new solutions
- Observed that sometimes people put themselves inside the problem
  - The problem solvers experienced a form of psychological inertia ➔ they wanted to protect their imaginary selves.

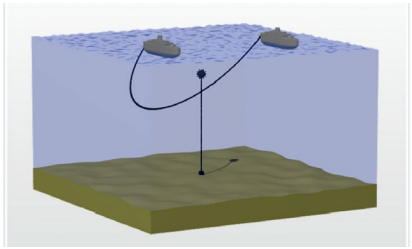
Smart Little People

- **Imagine a crowd of Smart Little People rather than just one person.**
  - *Visualize people being helpfully involved in solving the problem, but don't reject 'dangerous' solutions in case they get hurt.*
  - *With an infinite number of people who can solve the problem, it doesn't matter if a few thousand get destroyed*

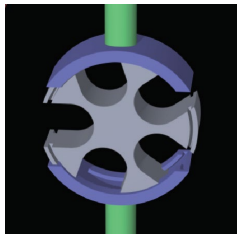
Example - Using Smart Little People

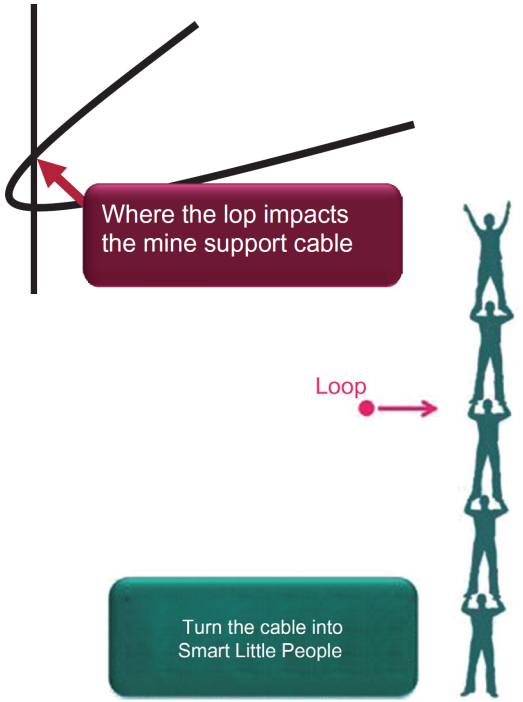


Using Smart Little People to illustrate a composite material



Minesweepers





The device which was developed and is now widely used works like a rotating door. It is based on the principle of the smart little person letting go with one hand to let the cable pass through while still hanging on with the other hand. Then rejoining the first hand and letting go with the second hand so the cable passes through but the vertical link is always maintained.

2

Research Meeting
Conceptual Design on Car for Optimum Parking Space

(N. Manohar, Praveen Kalla)

TU/e

TRIZ - Examples

Research Meeting

Conceptual Design on Car for Optimum Parking Space

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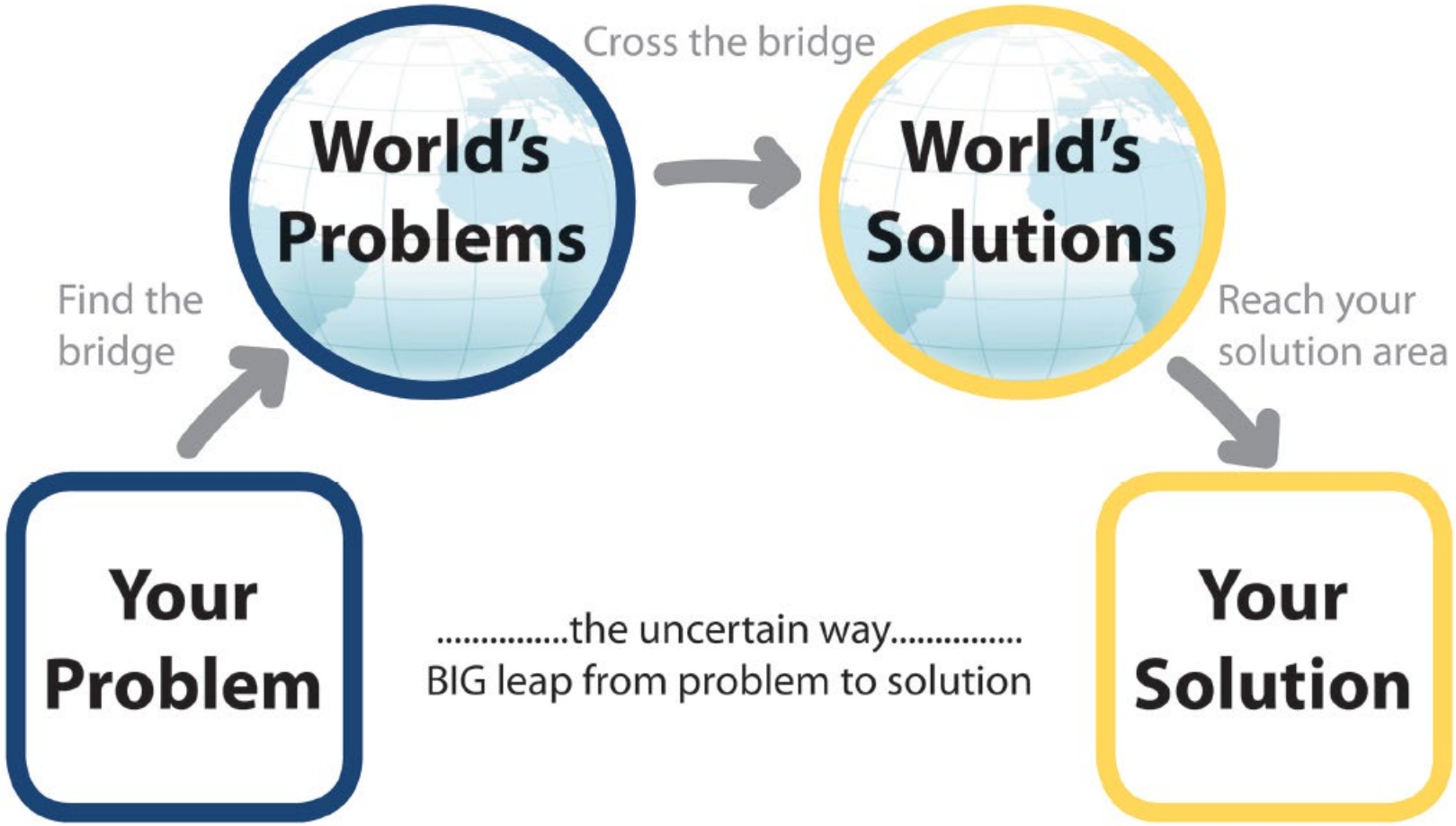
TRIZ Problem Solving



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TRIZ Example

- **Innovative Conceptual Design on Car using TRIZ Method for Optimum Parking Space**
  - *In many areas, especially urban areas, parking is a serious problem. Shortages of parking space, complaints about high parking tariffs and congestion due to visitors in search for a parking place are only a few examples of everyday parking problems. Many cities and urban areas recognize these problems, but the solution proves to be very complicated. In the, MIT City Car Electric Automobile, developed and prototyped by Smart Cities, is designed to meet the demand for enclosed personal mobility Design and Computation program. It presents a proposal for urban transportation based on the design of a small collapsible vehicle. Problems associated with travel by passengers, although every developed country has built important infrastructure in the form of roads. Based on this problems, the conceptual car design architecture has that expand/contract the car when it have required front transmission system, independent suspension system and dampers at chassis for minimize vibrations. Computer Aided Engineering (CAE) used to design the model of a conceptual car. By approaching TRIZ theory is employed to assist the way to get new drawing which is used to resolve the contradiction. The 40 engineering principles are also used as the design guideline. The finite element used to validate the strength of the new telescopic chassis based on the car body design.*

Contradictions

- Car design improve feature parameters consist of:
  - length of moving object (3)
  - volume of moving object (7)
  - shape (12)
  - strength (14)
- Parameters to be deteriorated are:
  - reliability (27)
  - weight of moving object (1)

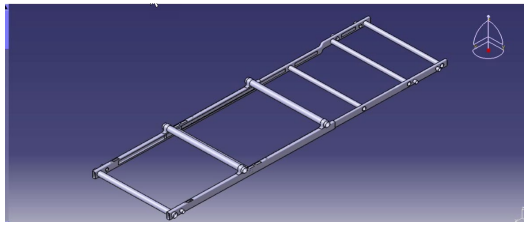
Worsening factor / Improving factor	Weight of moving object (1)	Reliability (27)
Length of moving object (3)	8, 15, 29, 34	
Volume of moving object (7)	2, 26, 29,40	
Shape (12)		10, 40, 16
Strength (14)	1, 8, 40, 15	

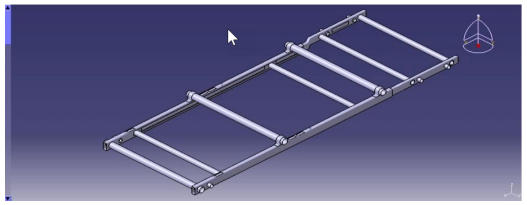
1. Segmentation
2. Extraction, Separation, Removal, Segregation
3. Local Quality
4. Asymmetry
5. Combining, Integration, Merging
6. Universality, Multi-functionality
7. Nesting
8. Counterweight, Levitation (2)
9. Preliminary anti-action, Prior counteraction
10. Prior action
11. Cushion in advance, compensate before
12. Equipotentiality, remove stress
13. Inversion, The other way around
14. Spheroidality, Curvilinearity
15. Dynamicity, Optimization (2)
16. Partial or excessive action
17. Moving to a new dimension
18. Mechanical vibration/oscillation
19. Periodic action
20. Continuity of a useful action
21. Rushing through
22. Convert harm into benefit, Blessing in disguise“
23. Feedback
24. Mediator, intermediary
25. Self-service, self-organization
26. Copying
27. Cheap, disposable objects
28. Replacement of a mechanical system with 'fields'
29. Pneumatics or hydraulics (2)
30. Flexible membranes or thin film
31. Use of porous materials
32. Changing color or optical properties
33. Homogeneity
34. Rejection and regeneration, Discarding and recovering
35. Transformation of the physical and chemical states of an object, parameter change, changing properties
36. Phase transformation
37. Thermal expansion
38. Use strong oxidizers, enriched atmospheres, accelerated oxidation
39. Inert environment or atmosphere
40. Composite materials (3)

SOLUTION

- The above contradiction matrix step aims to increases/decreases the car volume by using hydraulic or pneumatic system.
- The major car design consists of *car chassis frame* and *car body structure*.

Type of chassis	Length of chassis	Width of chassis Front	rear	Mass of chassis
Smart chassis	3850 mm	1350 mm	1388 mm	175 kg
Expandable chassis	4850 mm	1350 mm	1388 mm	175 kg





AUTOMOTIVE CONTRADICTION

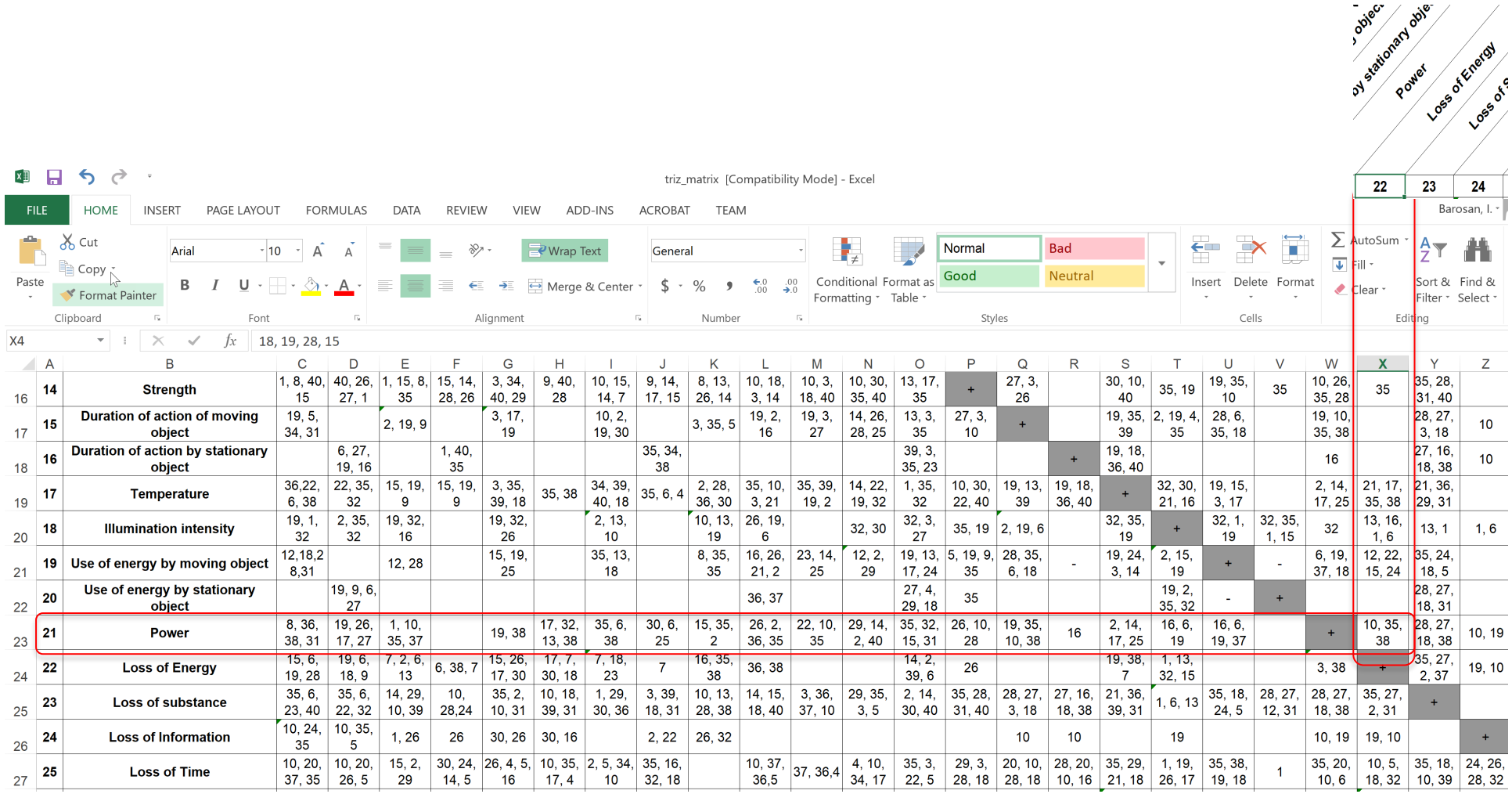
Technical Contradictions Automotive

- *The vehicle has higher horsepower, but uses more fuel*
- *The vehicle has high acceleration but uses more fuel*
- *The ride feels smoother, but the handling is difficult on high speed curves*
- *A pick-up truck has high load capacity (stiff rear suspension) but the ride is rough.*
- *Putting controls on stalks increases driver convenience, but makes assembly of the steering column more complex.*
- *Electric vehicles can go long distances between recharging, but the battery weight gets too high to move at all*

Example 1

- *The vehicle has higher horsepower, but uses more fuel*
- Local Parameters:
  - *higher horsepower → Improve*
  - *more fuel → Get Worse*
- *Global Parameters*
  - *Horsepower → Power – 21*
  - *Fuel → Use of Energy by Moving Object – 19*
  - *Fuel → Loss of Energy – 22*
  - *Fuel → Loss of Substance – 23*

Example 1



triz_matrix [Compatibility Mode] - Excel

																							22	23	24
																							↓	↓	↓
																							Power	Loss of Energy	Loss of s
16	14	Strength	1, 8, 40, 15	40, 26, 27, 1	1, 15, 8, 35	15, 14, 28, 26	3, 34, 40, 29	9, 40, 28	10, 15, 14, 7	9, 14, 17, 15	8, 13, 26, 14	10, 18, 3, 14	10, 3, 18, 40	10, 30, 35, 40	13, 17, 35	+	27, 3, 26		30, 10, 40	35, 19	19, 35, 10	35	10, 26, 35, 28	35	35, 28, 31, 40	
17	15	Duration of action of moving object	19, 5, 34, 31		2, 19, 9		3, 17, 19		10, 2, 19, 30		3, 35, 5	19, 2, 16	19, 3, 27	14, 26, 28, 25	13, 3, 35	27, 3, 10	+		19, 35, 39	2, 19, 4, 35	28, 6, 35, 18		19, 10, 35, 38		28, 27, 3, 18	10
18	16	Duration of action by stationary object		6, 27, 19, 16		1, 40, 35				35, 34, 38					39, 3, 35, 23			+	19, 18, 36, 40				16		27, 16, 18, 38	10
19	17	Temperature	36,22, 6, 38	22, 35, 32	15, 19, 9	15, 19, 9	3, 35, 39, 18	35, 38	34, 39, 40, 18	35, 6, 4	2, 28, 36, 30	35, 10, 3, 21	35, 39, 19, 2	14, 22, 19, 32	1, 35, 32	10, 30, 22, 40	19, 13, 39	19, 18, 36, 40	+	32, 30, 21, 16	19, 15, 3, 17		2, 14, 17, 25	21, 17, 35, 38	21, 36, 29, 31	
20	18	Illumination intensity	19, 1, 32	2, 35, 32	19, 32, 16		19, 32, 26		2, 13, 10		10, 13, 19	26, 19, 6		32, 30	32, 3, 27	35, 19	2, 19, 6		32, 35, 19	+	32, 1, 19	32, 35, 1, 15	32	13, 16, 1, 6	13, 1	1, 6
21	19	Use of energy by moving object	12,18,28,31		12, 28		15, 19, 25		35, 13, 18		8, 35, 35	16, 26, 21, 2	23, 14, 25	12, 2, 29	19, 13, 17, 24	5, 19, 9, 35	28, 35, 6, 18	-	19, 24, 3, 14	2, 15, 19	+	-	6, 19, 37, 18	12, 22, 15, 24	35, 24, 18, 5	
22	20	Use of energy by stationary object		19, 9, 6, 27								36, 37			27, 4, 29, 18	35				19, 2, 35, 32	-	+			28, 27, 18, 31	
23	21	Power	8, 36, 38, 31	19, 26, 17, 27	1, 10, 35, 37		19, 38	17, 32, 13, 38	35, 6, 38	30, 6, 25	15, 35, 2	26, 2, 36, 35	22, 10, 35	29, 14, 2, 40	35, 32, 15, 31	26, 10, 28	19, 35, 10, 38	16	2, 14, 17, 25	16, 6, 19	16, 6, 19, 37		+	10, 35, 38	28, 27, 18, 38	10, 19
24	22	Loss of Energy	15, 6, 19, 28	19, 6, 18, 9	7, 2, 6, 13	6, 38, 7	15, 26, 17, 30	17, 7, 30, 18	7, 18, 23	7	16, 35, 38	36, 38			14, 2, 39, 6	26			19, 38, 7	1, 13, 32, 15			3, 38	+	35, 27, 2, 37	19, 10
25	23	Loss of substance	35, 6, 23, 40	35, 6, 22, 32	14, 29, 10, 39	10, 28,24	35, 2, 10, 31	10, 18, 39, 31	1, 29, 30, 36	3, 39, 18, 31	10, 13, 28, 38	14, 15, 18, 40	3, 36, 37, 10	29, 35, 3, 5	2, 14, 30, 40	35, 28, 31, 40	28, 27, 3, 18	27, 16, 18, 38	21, 36, 39, 31	1, 6, 13	35, 18, 24, 5	28, 27, 12, 31	28, 27, 18, 38	35, 27, 2, 31	+	
26	24	Loss of Information	10, 24, 35	10, 35, 5	1, 26	26	30, 26	30, 16		2, 22	26, 32						10	10		19			10, 19	19, 10		+
27	25	Loss of Time	10, 20, 37, 35	10, 20, 26, 5	15, 2, 29	30, 24, 14, 5	26, 4, 5, 16	10, 35, 17, 4	2, 5, 34, 10	35, 16, 32, 18		10, 37, 36,5	37, 36,4	4, 10, 34, 17	35, 3, 22, 5	29, 3, 28, 18	20, 10, 28, 18	28, 20, 10, 16	35, 29, 21, 18	1, 19, 26, 17	35, 38, 19, 18	1	35, 20, 10, 6	10, 5, 18, 32	35, 18, 10, 39	24, 26, 28, 32

Example 1

- **Principles: 10, 35, 38**
- 10 - *Prior action*
- 35 - *Transformation of the physical and chemical states of an object, parameter change, changing properties*
- 38 - *Use strong oxidizers, enriched atmospheres, accelerated oxidation*

Example 1: 10. Preliminary Action

- Perform, before it is needed, the required change of an object or system (either fully or partially)
- Prearrange objects such that they can come into action from the most convenient place and without losing time for their delivery
- **Examples:**

1. *A special fuel filter to remove excess water from the fuel to achieve target engine performance without complex combustion system*

Example 1: 35. Parameter Change

- Change an object's physical state (e.g. to a gas, liquid, or solid).
- Change the concentration or consistency
- Change the degree of flexibility.
- Change the temperature.
- **Examples:**

1. *Change the intake manifold length to get higher volumetric efficiency and lower pressure drop in engine*
2. *Use of pulsed spark plug using capacitor for amplifying voltage for wider spread of spark area for higher efficiency and lower emissions*

Example 1: 38. Strong Oxidants

- Replace common air with oxygen-enriched air (enriched atmosphere).
- Replace enriched air with pure oxygen (highly enriched atmosphere).
- Expose air or oxygen to ionizing radiation.
- Use ionized oxygen.
- Replace ozonized (or ionized) oxygen with ozone (atmosphere enriched by 'unstable' elements).
- **Examples:**

1. *Use of oxygen rich air for combustion for cleaner combustion and higher efficiency (L. Bool, 2002)*
2. *Use of DOC (Diesel Oxidation Catalyst) to oxidize unburned hydrocarbon in engine (MECA, Dec-2007)*
3. *Use of nitrous oxide to inject excessive oxygen in combustion for higher power*

3

TRIZ – Airbag Example

Link:
https://www.youtube.com/watch?v=pJZmFeVyazo

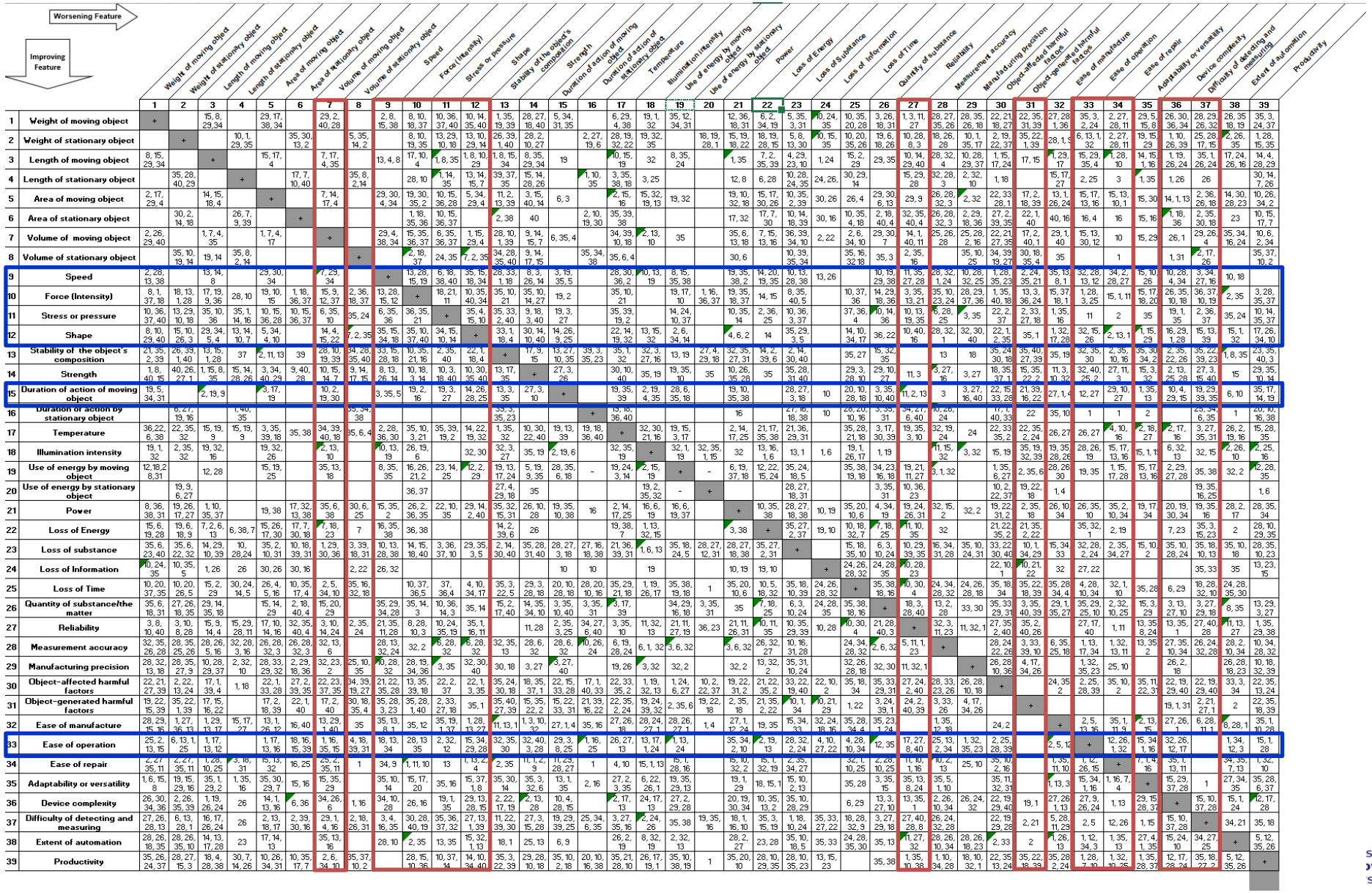
Air Bag Examples

- Examples:
  1. *If the threshold for deployment is set low, protecting belted occupants, more unbelted small people in the passenger seat are injured.*
  2. *If the threshold for deployment is set high, unbelted passengers are protected from air bag-caused injury, but belted passengers suffer more injury from the collision.*

Air Bag Examples

3. *High power ("aggressive") deployment saves lives of average-sized drivers, but increases injuries to unbelted or small passengers.*
4. *Adding more sensors (and **data processing**) to customize the deployment to the circumstances, and thereby save lives of small and unbelted people, increases the complexity of the system.*
5. *Adding more sensors (and data processing) to customize the deployment to the circumstances, and thereby save lives of small and unbelted people, decreases the reliability of the system.*

Contradiction Matrix



Solution - Principle 21. Skipping

- A. Conduct a process , or certain stages (e.g. destructible, harmful or hazardous operations) at high speed.
  - *Use a high speed dentist's drill to avoid heating tissue.*
  - *Cut plastic faster than heat can propagate in the material, to avoid deforming the shape.*

1. *Inflate the air bag faster than current practice, so that it is fully inflated when the small person impacts it.*

Solution - Principle 39. Inert atmosphere

- A. Replace a normal environment with an inert one.
- B. Add neutral parts, or inert additives to an object.

1. *The bag acts "hard" because of its motion.*
2. *So something that would "soften" the surface would be the equivalent of an "inert" material-it does not prevent the original purpose (inflate the bag and protect the person from hitting solid objects) but it cushions the blow from the bag itself.*
3. *Change the structure of the bag-make it corrugated, or make it of filaments, or use multiple crushable layers.*
4. *Change the "hardness" without changing the structure (this is the 2-stage inflation that has already been proposed.)*

Solution - Principle 16. Partial or excessive actions

- A. Using ‘slightly less’ or ‘slightly more’ of the same method, the problem may be considerably easier to solve.
- *The de-powered air bag has been proposed as a solution of this type.*
  1. *By using less power, the acceleration of the bag is less, and injuries will be reduced.*
  2. *Conversely, smaller bags with higher power would reach full inflation sooner that the passenger would be protected from the accident and not injured by the air bag*

Solution - Principle 22. “Blessing in disguise” or “Turn Lemons into Lemonade”

- A. Use harmful factors (particularly, harmful effects of the environment or surroundings) to achieve a positive effect.
  - *Use waste heat to generate electric power.*
  - *Recycle waste (scrap) material from one process as raw materials for another.*

1. *Use the relative motion of the person and the vehicle as part of the protection.*
2. *Design other parts of the system (seat, dash, side panels) to redirect the moving person to be properly placed for best air-bag protection.*

Solution - Principle 22. “Blessing in disguise” or “Turn Lemons into Lemonade”

- B. Eliminate the primary harmful action by adding it to another harmful action to resolve the problem.
  1. *Add a buffering material to a corrosive solution.*
  2. *Use a helium-oxygen mix for diving, to eliminate both nitrogen narcosis and oxygen poisoning from air and other nitrox mixes.*

Solution - Principle 22. “Blessing in disguise” or “Turn Lemons into Lemonade”

- C. Amplify a harmful factor to such a degree that it is no longer harmful.

1. *Use a backfire to eliminate the fuel from a forest fire*
2. *This again suggests inflating the air bag faster, so that it is no longer harmful by the time the person reaches it.*

Physical Contradictions

- The deployment threshold should be high but it should be low
- TRIZ has 4 classical ways to resolve physical contradictions
  - *Separation in time*
  - *Separation in space*
  - *Phase transition*
    - Solid – liquid – gas – plasma
    - Paramagnetic -Ferromagnetic
    - Others-ferroelectric, superconducting, crystal structure, …
  - *Move to the super-system or the sub-system*

Physical to Technical Contradictions

- To resolve a physical contradiction: ***convert it to a technical contradiction.***
- The conversion may be obvious or subtle: ***the most useful technique is to separate the elements of the contradiction and ask "WHY?"***
- For example, continuing with the high/low deployment threshold contradiction:
  - *Why must it be high? To avoid deployment in low-speed accidents and prevent air bag-caused injuries*
  - *Why must it be low? To protect people in accidents at any speed*
  - *This leads us to the technical contradiction*
  - *As speed of the car increases, injuries to occupants become worse*

4

TRIZ – Design Principles

(Adapted from Slides Developed by Darryl Mann, Creax)

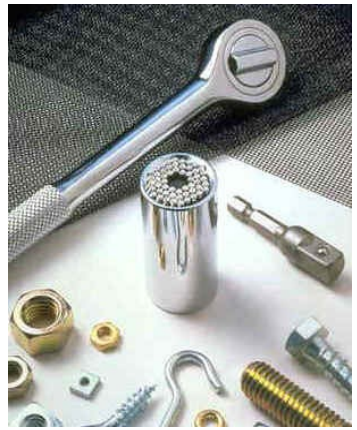
TRIZ – 40 Principles

1 Segmentation
2 Taking out
3 Local quality
4 Asymmetry
5 Merging
6 Universality
7 Russian dolls
8 Anti-weight
9 Preliminary anti-action
10 Preliminary action
11 Beforehand cushioning
12 Equipotentiality
13 "The other way round"
14 Spheroidality - Curvature
15 Dynamics
16 Partial or excessive actions
17 Another dimension
18 Mechanical vibration
19 Periodic action
20 Continuity of useful action
21 Skipping
22 Blessing in disguise
23 Feedback
24 Intermediary
25 Self-service
26 Copying
27 Cheap short-lived objects
28 Mechanics substitution
29 Pneumatics and hydraulics
30 Flexible shells and thin films
31 Porous materials
32 Colour changes
33 Homogeneity
34 Discarding and recovering
35 Parameter changes
36 Phase transitions
37 Thermal expansion
38 Strong oxidants
39 Inert atmosphere
40 Composite materials

Principle 1. Segmentation

A - Divide an object into independent parts

- Gator-grip socket spanner
- Multi-pin connectors
- Bubble-wrap
- Have a range of different focal length lenses for a camera
- Multiple pistons in an internal combustion engine
- Multi-engined aircraft
- Pocket-spring mattress
- Stratification of different constituents inside a chemical process vessel



B - Make an object easy to assemble or disassemble

- Rapid-release bicycle saddle/wheel/etc fasteners
- Quick disconnect joints in plumbing and hydraulic systems
- Single fastener V-band clamps on flange joints
- Loose-leaf paper in a ring-binder

C - Increase the degree of fragmentation or segmentation

- Use of multiple control surfaces on aerodynamic structures
- 16 and 24 valve versus 8 valve internal combustion engines
- Multi-blade cartridge razors
- Multi-zone combustion systems
- Build up a component from layers (e.g. stereo-lithography, welds, etc)

Principle 2. Taking Out

A - Separate an interfering part or property from an object, or single out the only necessary part (or property) of an object

- Locate a noisy compressor outside the building where the compressed air is used
- Use the sound of a barking dog, without the dog, as a burglar alarm
- Scarecrow
- Non-smoking areas in restaurants or in railway carriages
- Automation removes humans

Principle 3. Local Quality

A - Change an object's structure from uniform to non-uniform

- Reduce drag on aerodynamic surfaces by adding riblets or 'shark-skin' protrusions
- Moulded hand grips on tools
- Drink cans shaped to facilitate stable stacking
- Material surface treatments/coatings - plating, erosion/corrosion protection, non-stick, etc

B - Change an external environment (or external influence) from uniform to non-uniform

- Use a temperature, density, or pressure gradient instead of constant temperature, density or pressure
- Introduce turbulent flow around an object to alter heat transfer properties

C - Make each part of an object function in conditions most suitable for its operation

- Freezer compartment in refrigerator
- Different zones in the combustion system of an engine

D - Make each part of an object fulfil a different and/or complementary useful function.

- Swiss-Army knife
- Combined can and bottle opener
- Hammer with nail puller

Principle 4. Asymmetry

A - Change the shape or properties of an object from symmetrical to asymmetrical

- Introduce a geometric feature which prevents incorrect usage/assembly of a component (e.g. earth pin on electric plug)
- Asymmetrical funnel allows higher flow-rate than normal funnel
- Put a flat spot on a cylindrical shaft to attach a locking feature
- Oval and complex shaped O-rings
- Introduction of angled or scarfed geometry features on component edges
- Cam
- Ratchet
- Aerofoil – asymmetry generates lift
- Eccentric drive
- Blohm und Voss observation aircraft

B - Change the shape of an object to suit external asymmetries (e.g. ergonomic features)

- Car steering system compensates for camber in road
- Wing design compensated for asymmetric flow produced by propeller
- Turbomachinery design takes account of boundary layer flows (‘end-bend’)

C - If an object is asymmetrical, increase its degree of asymmetry.

- Use of variable control surfaces to alter lift properties of an aircraft wing
- Special connectors with complex shape/pin configurations to ensure correct assembly
- Introduction of several different measurement scales on a ruler

Principle 5. Merging

A - Bring closer together (or merge) identical or similar objects or operations in space

- Automatic rifle/machine gun
- Multi-colour ink cartridges
- Multi-blade razors
- Bi-focal lens spectacles
- Double/triple glazing
- Strips of staples
- Catarmaran/trimaran

B - Make objects or operations contiguous or parallel; bring t...m ...ge...er in time

- Combine harvester
- Manufacture cells
- Grass collector on a lawn-mower
- Mixer taps
- Pipe-lined computer processors perform different stages in a calculation simultaneously
- Vector processors perform the same process on several sets of data in a single pass
- Fourier analysis – integration of many sine curves

Principle 6. Universality

A - Make a part or object perform multiple functions; eliminate the need for other parts

- Child's car safety seat converts to a stroller
- Home entertainment centre
- Swiss Army knife
- Grill in a microwave oven
- Radio-alarm clock
- Work-mate
- CD used as a storage medium for multiple data types
- Use of Standards in e.g. data exchange
- Cleaning strip at beginning of a cassette tape cleans tape heads
- Bathroom light-switch starts extractor fan
- Car glove compartment lid incorporates cup-holders
- Cordless drill also acts as screwdriver, sander, polisher, etc
- Fishing stool/container

Principle 7. Russian Dolls “Nested Doll”

A - Place one object inside another

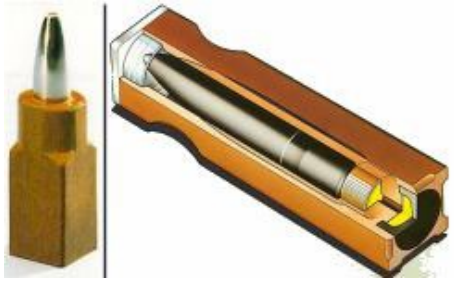
- Place a safe inside a wall or under floorboards
- Retractable aircraft under-carriage
- Introduce voids into 3D structures
- Injected cavity-wall insulation
- Paint-brush attached to inside of lid of nail-varnish, etc
- Lining inside a coat

B - Place multiple objects inside others

- Nested tables
- Telescope
- Measuring cups or spoons
- Stacking chairs
- Multi-layer erosion/corrosion coatings

C - Make one part pass (dynamically) through a cavity in the other.

- Telescopic car aerial
- Retractable power-lead in vacuum cleaner
- Seat belt retraction mechanism
- Tape measure
- Stacked charge ammunition



Principle 8. Anti-weight

A - To compensate for the weight of an object, merge it with other objects that provide lift

- Kayak with foam floats built into hull cannot sink
- Aerostatic aeroplane contains lighter-than-air pockets
- Hot air or helium balloon.
- Swim-bladder inside a fish
- Flymo cutting blade produces lift

B - To compensate for the weight of an object, make it interact with the environment (e.g. use aerodynamic, hydrodynamic, buoyancy and other forces)

- Vortex generators improve lift of aircraft wings
- Wing-in-ground effect aircraft
- Hydrofoils lift ship out of the water to reduce drag
- Make use of centrifugal forces in rotating systems (e.g .Watt governor)
- Maglev train uses magnetic repulsion to reduce friction

Principle 9. Preliminary Anti-action

A - If it will be necessary to perform an action with both harmful and useful effects, this action should be replaced with anti-actions to control harmful effects

- Make clay pigeons out of ice or dung in order that they do not have to be collected afterwards.
- Masking objects before harmful exposure: Use a lead apron on parts of the body not being exposed to X-rays, use masking tape when painting difficult edges, etc.
- Predict effects of signal distortion / attenuation and compensate before transmitting
- Buffer a solution to prevent harm from extremes of pH

B - Create beforehand stresses in an object that will oppose known undesirable working stresses later on.

- Pre-stress rebar before pouring concrete.
- Pre-stressed bolts
- Pre-shrunk jeans
- Decompression chamber

Principle 10. Preliminary Action

A - Perform, before it is needed, the required change of an object (either fully or partially)

- Pre-pasted wall paper
- Sterilize all instruments needed for a surgical procedure.
- Self-adhesive stamps
- Holes cut before sheet-metal part formed
- Pre-impregnated carbon fibre reduces lay-up time and improves "wetting“
- Explosive reactive armour

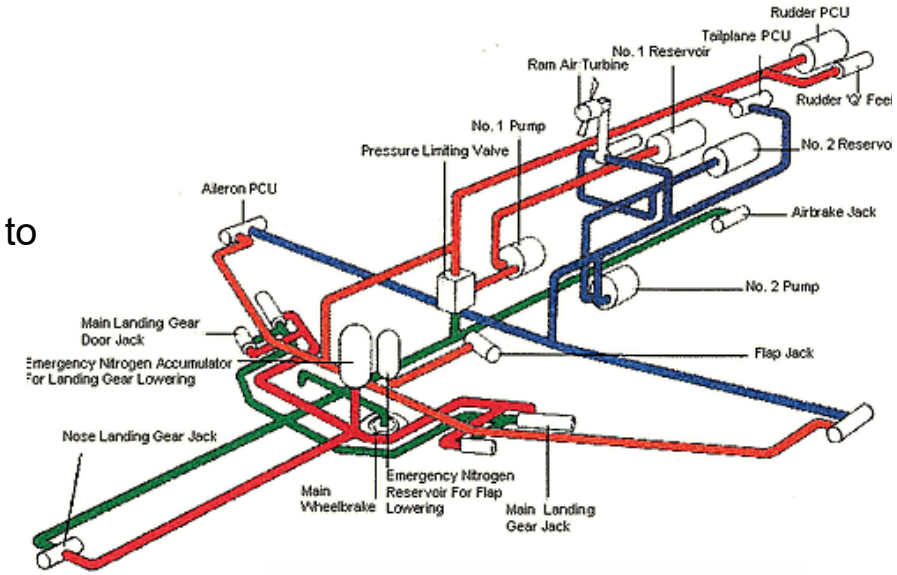
B - Pre-arrange objects such that they can come into action from the most convenient place and without losing time for their delivery

- Manufacture flow-lines
- Pre-deposited blade in a surgery cast facilitates removal.
- Car jack, wheel brace, and spare tyre stored together
- Collect all the tools and materials for the job before starting

Principle 11. Beforehand Cushioning

A - Prepare emergency means beforehand to compensate for the relatively low reliability of an object ('belt and braces')

- Magnetic strip on photographic film that directs the developer to compensate for poor exposure
- Back-up parachute
- Dual channel control system
- Air-bag in a car
- Spare wheel
- Relief valve
- Emergency lighting circuit
- Battery back-up
- Automatic save operations performed by computer programs
- Zip-files
- Mask borders of objects to be painted, use stencils
- Crash barriers on motorways
- 'Touch-down' bearing in magnetic bearing system
- Multiple hydraulic systems
- "Slime" puncture avoidance fluid



Principle 12. Equipotentiality

A - If an object has to be raised or lowered, redesign the object's environment so the need to raise or lower is eliminated or performed by the environment

- Canal locks
- Spring loaded parts delivery system in a factory
- Mechanic's pit in a garage means car does not have to be lifted.
- Place a heavy object on ice, and let ice melt in order to lower it.
- Angle-poise lamp; changes in gravitational potential stored in balancing springs
- Descending cable cars balance the weight of ascending cars

Principle 13. “The Other Way Round”

A - Invert the action(s) used to solve the problem (e.g. instead of cooling an object, heat it)

- To loosen stuck parts, cool the inner part instead of heating the outer part.
- Vacuum casting
- Test pressure vessel by varying pressure outside rather than inside the vessel
- Test seal on a liquid container by filling with pressurised air and immersing in liquid; trails of bubbles are easier to trace than slow liquid leaks
- Place nuts in a vacuum to get them out of their shells
- “Upside-down” motorcycle forks

B - Make movable parts (or the external environment) fixed, and fixed parts movable)

- Hamster wheel
- Rotate the part instead of the tool.
- Wind tunnels
- Moving sidewalk with standing people

C - Turn the object (or process) 'upside down'

- Clean bottles by inverting and injecting water from below; the water then drains by itself.
- Turn an assembly upside down to insert fasteners
- Open tinned beans from the bottom to get out beans that would otherwise have stuck to the bottom due to storage

Principle 14. Spheroidality - Curvature

A - Instead of using rectilinear parts, surfaces, or forms, use curvilinear ones; move from flat surfaces to spherical ones; from parts shaped as a cube (parallelepiped) to ball-shaped structures

- Use arches and domes for strength in architecture.
- Introduce stress relieving holes at the ends of slots
- Change curvature on lens to alter light deflection properties

B - Use rollers, balls, spirals, domes

- Spiral gear (Nautilus) produces continuous resistance for weight lifting.
- Use spherical casters instead of cylindrical wheels to move furniture
- Archimedes screw

C - Go from linear to rotary motion (or vice versa)

- Rotary actuators in hydraulic system.
- Switch from reciprocating to rotary pump
- Linear motors

D - Use centrifugal forces

- Centrifugal casting for even wall thickness structures
- Spin components after painting to remove excess paint
- Watt governor
- Vortex/cyclone separates different density objects

Principle 15. Dynamics

A - Allow (or design) the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition

- Adjustable steering wheel (or seat, or back support, or mirror position...)
- Gel fillings inside seat allow it to adapt to user
- Shape memory alloys/polymers.
- Racing car suspension adjustable for different tracks and driving techniques
- Telescopic curtain rail allows for "one size fits all"

B - Divide an object into parts capable of movement relative to each other

- Articulated lorry
- Folding chair/mobile phone/laptop/etc
- Brush seals

C - If an object (or process) is rigid or inflexible, make it movable or adaptive

- Bendy drinking straw
- Flexible joint
- Strimmer

D - Increase the degree of free motion

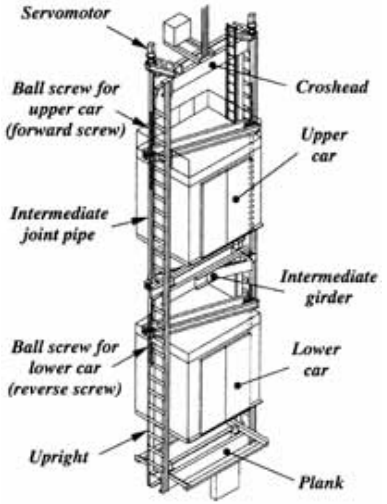
- Use of different stiffness fibres in toothbrush – easily deflected at the edges to prevent gum damage, hard in the middle
- Loose sand inside truck tyre gives it self-balancing properties at speed

Principle 16. Partial or Excessive Actions

A - If 100 percent of an object is hard to achieve using a given solution method then, by using 'slightly less' or 'slightly more' of the same method, the problem may be considerably easier to solve

- Over spray when painting, then remove excess.
- When painting walls, don't use the roller right up to the ceiling; touch up with a brush
- Fill, then "top off" when pouring a pint of Guinness.
- Shrink wrapping process uses plastic deformation of wrapping to accommodate variations in vacuum pressure.
- ‘Roughing’ and ‘Finish’ machining operations.
- Over-fill holes with plaster and then rub back to smooth.
- (Use of Pareto analysis to prioritise actions when not all can be achieved with the available resources.)

Principle 17. Another Dimension

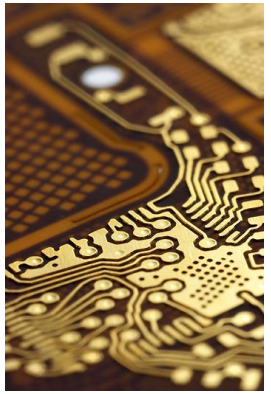


A - If an object contains or moves in a straight line, consider use of dimensions or movement outside the line

- Serrated or scalloped edges on a knife blade or hole punch
- Curved bristles on a brush
- Coiled telephone cable
- “Stacked” elevator Petronas towers

B - If an object contains or moves in a plane, consider use of dimensions or movement outside the current plane

- Spiral staircase uses less floor area
- Introduction of down and up slopes between stations on railway reduces train acceleration and deceleration power requirements
- Conical instead of plain flange joint



C - Use a multi-storey arrangement of objects instead of a single-storey arrangement

- Cassette with 6 CDs to increase music time and variety
- Multi-storey office blocks or car-parks

D - Tilt or re-orient the object, lay it on its side

- Dump truck

E - Use 'another side' of a given area.

- Mount computer chip components on both sides of a silicon card
- Fix a leaking car radiator or pipe by adding fluid sealant to the inside rather than trying to seal from outside
- Nokia QWERTY phone

Principle 18. Mechanical Vibration

A - Cause an object to oscillate or vibrate

- Electric carving knife with vibrating blades
- Shake/stir paint to mix before applying
- Hammer drill
- Vibrate during sieving operations to improve throughput.

B - Increase its frequency (even up to the ultrasonic)

- Ultrasonic cleaning
- Non-destructive crack detection using ultrasound

C - Use an object's resonant frequency

- Destroy gall stones or kidney stones using ultrasonic resonance.
- Ease bottle cleaning by pulsing washing action at resonant frequency of bottles

D - Use piezoelectric vibrators instead of mechanical ones

- Quartz crystal oscillations drive high accuracy clocks.
- Piezoelectric vibrators improve fluid atomisation from a spray nozzle

E - Use combined ultrasonic and electromagnetic field oscillations.

- Mixing alloys in an induction furnace
- Ultrasonic drying of films – combine ultrasonic with heat source

Principle 19. Periodic Action

A - Instead of continuous action, use periodic or pulsating actions

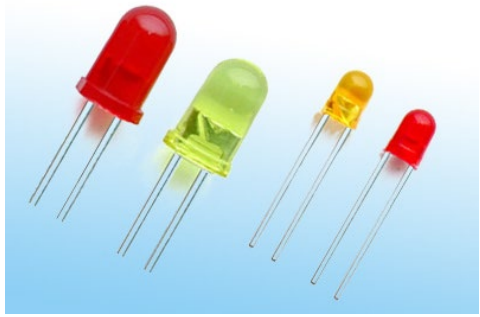
- Hitting something repeatedly with a hammer
- Pile drivers and hammer drills can exert far more force for a given weight
- Replace a continuous siren with a pulsed sound.
- Pulsed bicycle lights make cyclist more noticeable to drivers
- Pulsed vacuum cleaner suction improves collection performance
- Pulsed water jet cutting

B - If an action is already periodic, change the periodic magnitude or frequency

- Replace a pulsed siren with sound that changes amplitude and frequency.
- Washing machine/dish-washer water injection operates uses different cycles for different load types.
- Dots and dashes in Morse Code transmissions
- Use AM, FM, PWM to transmit information

C - Use pauses between actions to perform a different action

- Clean barrier filters by back-flowing them when not in use.
- Inkjet printer cleans heads between passes
- Brush between suction pulses in vacuum cleaner.
- Multiple conversations taking place along the same telephone transmission line.
- Use of energy storage means – e.g. batteries, fly-wheels, etc



Principle 20. Continuity of Useful Action

A - Carry on work continuously; make all parts of an object work at full load or optimum efficiency, all the time

- Flywheel stores energy when a vehicle stops, so the motor can keep running at optimum power.
- Constant output gas-turbine in hybrid car, or APU in aircraft, runs at highest efficiency all the time it is switched on.
- Constant speed/variable pitch propeller
- Self-tuning engine – constantly tunes itself to ensure maximum efficiency
- Heart pacemaker
- Improve composting process by continuously turning material to be composted.
- Continuous glass or steel production

B - Eliminate all idle or intermittent actions or work

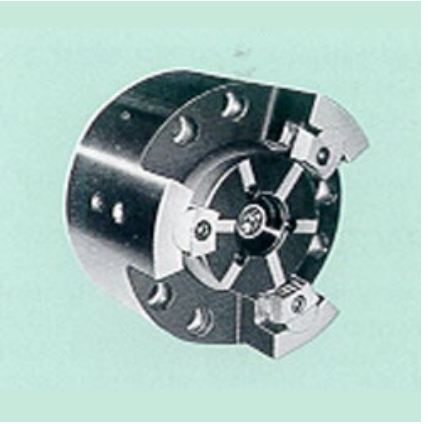
- Self-cleaning/self-emptying filter eliminates down-time
- Print during the return of a printer carriage--dot matrix printer, daisy wheel printers, inkjet printers.
- Digital storage media allow ‘instant’ information access (as opposed to tapes which require to be rewound)
- Kayaks use double-ended paddle to utilise "recovery" stroke
- Computer operating systems utilise idle periods to perform necessary "housekeeping" tasks.
- Rapid-drying paint

Principle 21. Skipping

A - Conduct a process , or certain stages (e.g. destructible, harmful or hazardous operations) at high speed

- Use a high speed dentist's drill to avoid heating tissue.
- Laser eye surgery
- Cut plastic faster than heat can propagate in the material, to avoid deforming the shape.
- Break toffee with an impulsive blow from a hammer
- Drop forge
- Flash photography
- Super-critical shaft – run through resonant modes quickly

Principle 22. Blessing in Disguise



A - Use harmful factors (particularly, harmful effects of the environment or surroundings) to achieve a positive effect

- Use waste heat to generate electric power.
- Use waste heat from engine to heat passenger cabin
- Recycle waste (scrap) material from one process as raw materials for another (e.g. chipboard)
- Use centrifugal energy in rotating shaft to do something useful – e.g. seal, or modulate cooling air
- Use pressure differences to help rather than hinder seal performance
- Centrifugal clamping in high speed chuck

B - Eliminate the primary harmful action by adding it to another harmful action to resolve the problem

- Add a buffering material to a corrosive solution (e.g. an alkali to an acid, or vice versa)
- Use a helium-oxygen mix for diving, to eliminate both nitrogen narcosis and oxygen poisoning from air and other nitrox mixes.

C - Amplify a harmful factor to such a degree that it is no longer harmful

- Use a backfire to eliminate the fuel from a forest fire.
- Use explosives to blow out an oil-well fire.
- Laser-knife cauterises skin/blood vessels as it cuts

Principle 23. Feedback

A - Introduce feedback (referring back, cross-checking) to improve a process or action

- Automatic volume control in audio circuits
- Signal from gyrocompass is used to control simple aircraft autopilots.
- Engine management system based on exhaust gas levels more efficient than carburettor
- Thermostat controls temperature accurately
- Statistical Process Control - Measurements are used to decide when to modify a process
- Feedback turns inaccurate op-amp into useable accurate amplifier

B - If feedback is already used, change its magnitude or influence in accordance with operating conditions

- Change sensitivity of an autopilot when within 5 miles of an airport.
- Change sensitivity of a thermostat when cooling vs. heating, since it uses energy less efficiently when cooling.
- Use proportional, integral and/or differential control algorithm combinations

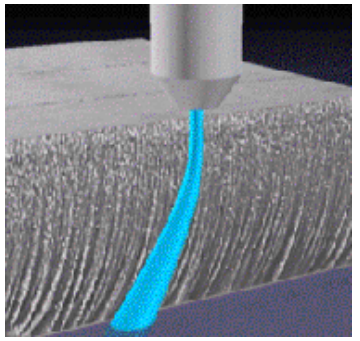
Principle 24. Intermediary

A - Use an intermediary carrier article or intermediary process

- Play a guitar with a plectrum
- Use a chisel to control rock breaking/sculpting process
- Drink coasters
- Dwell period during a manufacture process operation

B - Merge one object temporarily with another (which can be easily removed)

- Gloves to get hot dishes out of an oven
- Joining papers with a paper clip
- Introduction of catalysts into chemical reaction
- Abrasive particles enhance water jet cutting



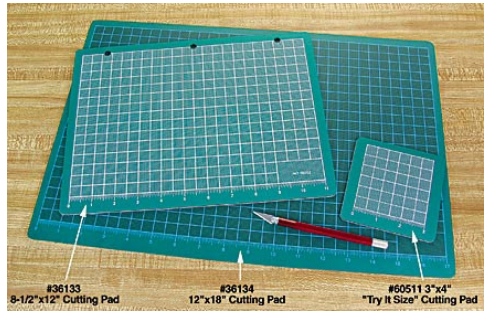
Principle 25. Self-service

A - Make an object serve or organise itself by performing auxiliary helpful functions

- A soda fountain pump that runs on the pressure of the carbon dioxide that is used to "fizz" the drinks. This assures that drinks will not be flat, and eliminates the need for sensors.
- Halogen lamps regenerate the filament during use--evaporated material is redeposited.
- Self-aligning/self-adjusting seal
- Self-locking nut
- Self-cleaning oven/glass/material
- Self-repairing structures
- Abradable materials used in engines such that initial running-in ‘cuts’ optimum seals into lining
- “Self-healing” cutting mat.

B - Use waste resources, energy, or substances

- Use heat from a process to generate electricity: "Co-generation".
- Use animal waste as fertilizer.
- Use food and lawn waste to create compost.
- Use pressure difference to reinforce seal action



Principle 26. Copying

A - Instead of an unavailable, expensive, fragile object, use simpler and inexpensive copies

- Imitation jewellery.
- Astroturf
- Crash test dummy
- UAV excludes pilot

B - Replace an object, or process with optical copies

- Do surveying from space photographs instead of on the ground.
- Measure an object by scaling measurements from a photograph.
- Laser anemometry
- Virtual reality
- Virtual mock-ups/electronic pre-assembly modelling

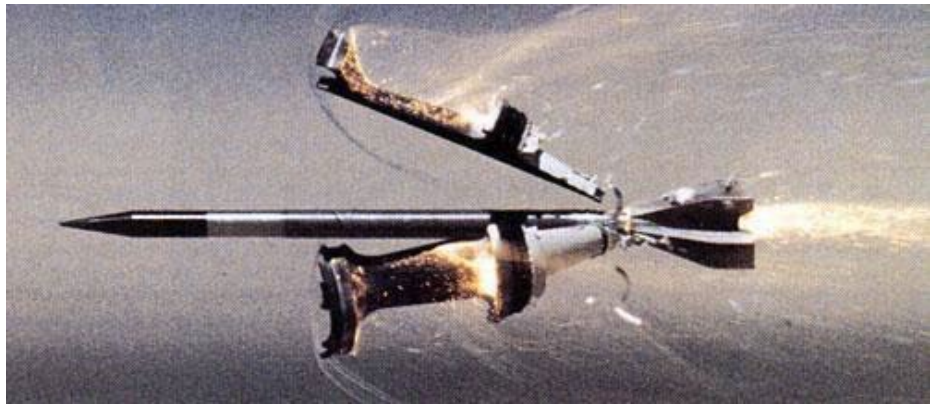
C - If visible optical copies are already used, move to infrared or ultraviolet copies

- Make images in infrared to detect heat sources, such as diseases in crops, or intruders in a security system.
- Use UV as a non-destructive crack detection method
- UV light used to attract flying insects into trap

Principle 27. Cheap Short-Lived Objects

A - Replace an expensive object with a multiple of inexpensive objects, compromising certain qualities, such as service life

- Disposable nappies/paper-cups/plates/cameras/torches/etc
- Matches versus lighters
- Throw-away cigarette lighters
- Industrial diamonds used in cutting tools
- Sacrificial coatings/components
- Post-Its
- Discarding-sabot armour piercing round.



Principle 28. Mechanics Substitution

A - Replace a mechanical means with a sensory (optical, acoustic, taste or smell) means

- Replace a physical fence to confine a dog or cat with an acoustic "fence" (signal audible to the animal).
- Finger-print/retina/etc scan instead of a key

B - Use electric, magnetic and electromagnetic fields to interact with the object

- Magnetic bearings
- Electrostatic precipitators separate particles from airflow
- Improve efficiency of paint-spraying by oppositely charging paint droplets and object to be painted.

C - Change from static to movable fields, from unstructured fields to those having structure

- Early communications used omnidirectional broadcasting. We now use antennas with very detailed structure of the pattern of radiation.
- Magnetic Resonance Imaging (MRI) scanner

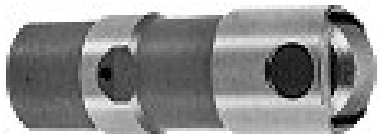
D - Use fields in conjunction with field-activated (e.g. ferromagnetic) particles

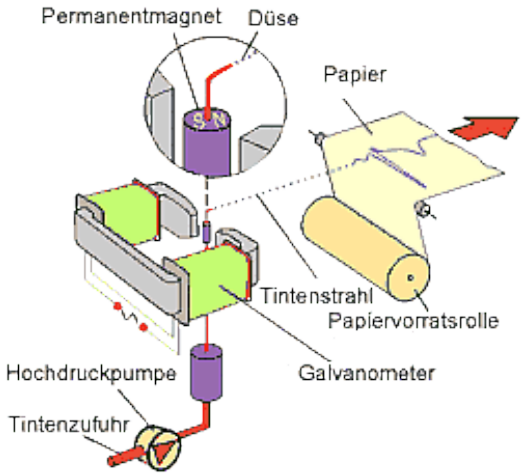
- Heat a substance containing ferromagnetic material by using varying magnetic field. When the temperature exceeds the Curie point, the material becomes paramagnetic, and no longer absorbs heat.
- Magneto-rheological effect – uses ferromagnetic particles and variable magnetic field to alter the viscosity of a fluid

Principle 29. Pneumatics and Hydraulics

A - Use gas and liquid parts of an object instead of solid parts (e.g. inflatable, filled with liquids, air cushion, hydrostatic, hydro-reactive)

- Transition from mechanical to hydraulic or pneumatic drive
- Inflatable furniture/mattress/etc
- Gel filled saddle adapts to user
- Hollow section O-rings
- Hovercraft
- Gas bearings
- Acoustic panels incorporating Helmholz resonators
- Hydraulic tappets





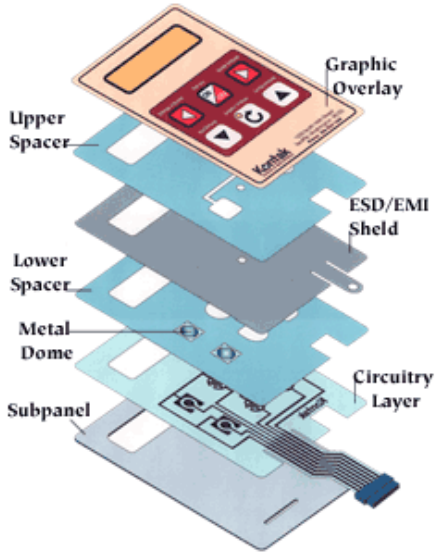
Principle 30. Flexible Shells and Thin Films

A - Use flexible shells and thin films instead of three dimensional structures

- Use inflatable (thin film) structures.
- Taut-liner trucks
- Tarpaulin car cover instead of garage
- Webbing
- Store energy in flexible/stretchable bags – e.g. accumulators in a hydraulic system
- Membrane keyboards

B - Isolate the object from the external environment using flexible shells and thin films

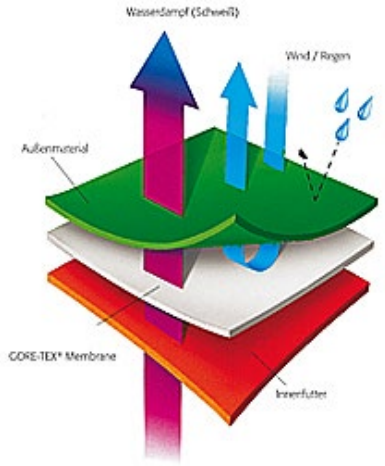
- Bubble-wrap
- Bandages/plasters
- Egg-box
- Tea bag



Principle 31. Porous Materials

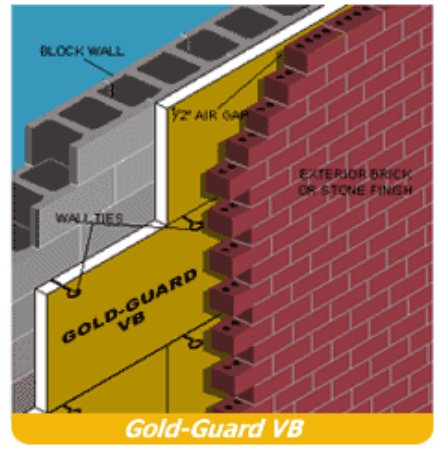
A - Make an object porous or add porous elements (inserts, coatings, etc.)

- Drill holes in a structure to reduce the weight.
- Cavity wall insulation
- Transpiration film cooled structures
- Foam metals
- Use sponge-like structures as fluid absorption media
- Goretex fabric



B - If an object is already porous, use the pores to introduce a useful substance or function

- Use a porous metal mesh to wick excess solder away from a joint.
- Store hydrogen in the pores of a palladium sponge. (Fuel "tank" for the hydrogen car--much safer than storing hydrogen gas)
- Dessicant in polystyrene packing materials
- Medicated swabs/dressings



Principle 32. Colour Changes

A - Change the colour of an object or its external environment

- Use safe lights in a photographic darkroom.
- Use colour-changing thermal paint to measure temperature
- Light-sensitive glasses
- Camouflage
- Employ interference fringes on surface structures to change colour (as in butterfly wings, etc)
- Colour changing plastic/temperature sensitive for child feeding spoon

B - Change the transparency of an object or its external environment

- Use photolithography to change transparent material to a solid mask for semiconductor processing.
- Smoke-screen

C - In order to improve observability of things that are difficult to see, use coloured additives or luminescent elements

- Fluorescent additives used during UV spectroscopy
- Use opposing colours to increase visibility – e.g. butchers use green decoration to make the red in meat look redder

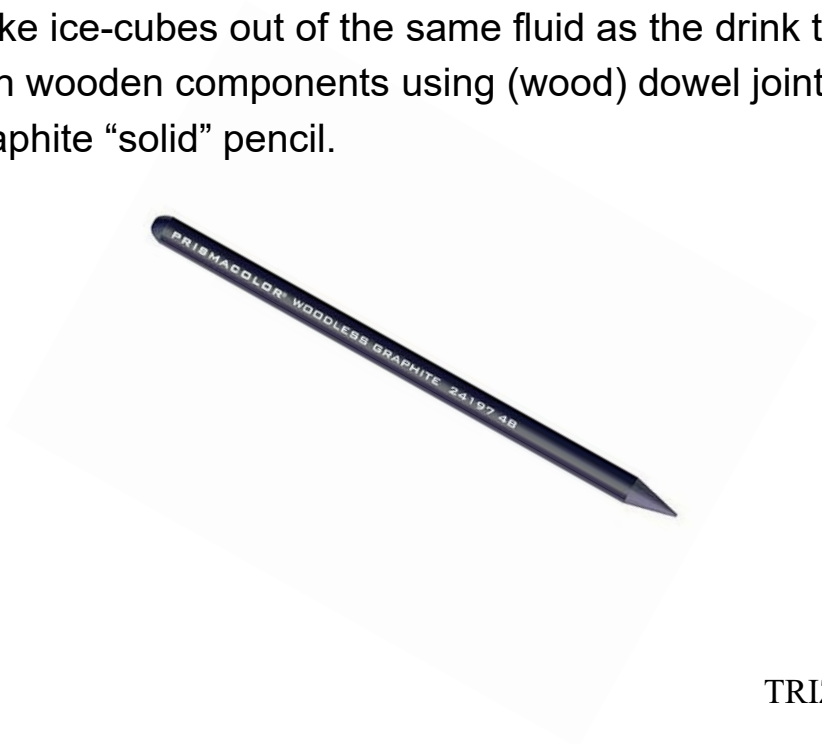
D - Change the emissivity properties of an object subject to radiant heating

- Use of black and white coloured panels to assist thermal management on space vehicles.
- Paint object with high emissivity paint in order to be able to measure it's temperature with a calibrated thermal imager

Principle 33. Homogeneity

A - Make objects interacting with a given object of the same material (or material with identical properties)

- Make the container out of the same material as the contents, to reduce chemical reactions.
- Friction welding requires no intermediary material between the two surfaces to be joined.
- ‘Liquid paper’ for correcting mistakes when writing
- Temporary plant pots made out of compostable material
- Human blood transfusions/transplants, use of bio-compatible materials
- Make ice-cubes out of the same fluid as the drink they are intended to cool
- Join wooden components using (wood) dowel joints
- Graphite “solid” pencil.



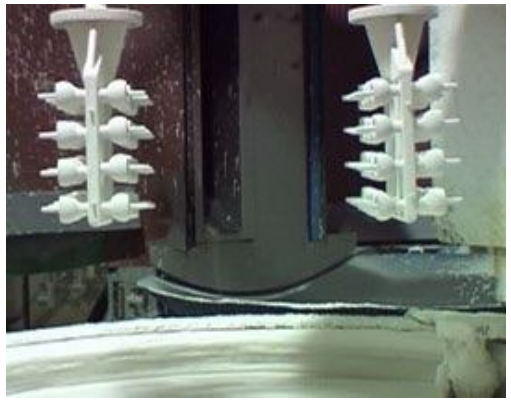
Principle 34. Discarding and Recovering

A - Make portions of an object that have fulfilled their functions go away (discard by dissolving, evaporating, etc.) or modify these directly during operation

- Use a dissolving capsule for medication.
- Ice structures: use water ice or carbon dioxide (dry ice) to make a template for a rammed earth structure, such as a temporary dam. Fill with earth, then, let the ice melt or sublime to leave the final structure.
- Bio-degradable containers, bags, etc.
- Casting processes – lost-wax, sand, etc.
- Sacrificial anode

B - Conversely, restore consumable parts of an object directly in operation

- Self-sharpening blades – knives/lawn-mowers/etc
- Strimmer dispenses more wire automatically after a breakage.
- Self-tuning automobile engines
- Propelling pencil
- Automatic rifle



Principle 35. Parameter Changes

A - Change an object's physical state (e.g. to a gas, liquid, or solid)

- Transition from mechanical to fluid or electrical drives
- Vaporise (or freeze) mercury to ease placing of very small amounts into fluorescent light-bulb

B - Change the concentration or consistency

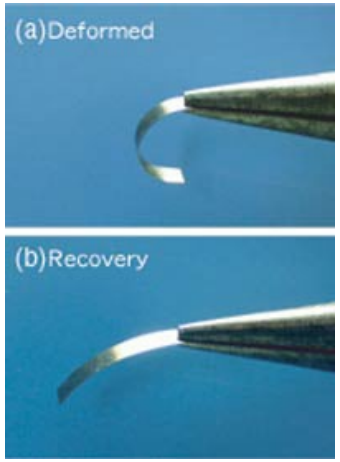
- Liquid versus bar or powder detergents.
- Abradable linings used for gas-turbine engine seals

C - Change the degree of flexibility

- Use adjustable dampers to reduce the noise of parts falling into a container by restricting the motion of the walls of the container.
- Compliant brush seals rather than labyrinth or other fixed geometry seals

D - Change the temperature

- Raise the temperature above the Curie point to change a ferromagnetic substance to a paramagnetic substance.
- Lower the temperature of medical specimens to preserve them for later analysis



E - Change the pressure.

- Pressure cooker cooks more quickly and without losing flavours.
- Electron beam welding in a vacuum.

F - Change other parameters

- Shape memory alloys/polymers
- Use high conductivity materials – e.g. carbon fibre

Principle 36. Phase Transitions

A - Use phenomena occurring during phase transitions (e.g. volume changes, loss or absorption of heat, etc.)

- Latent heat effects in melting/boiling
- Soak rocks in water, then freezing causes water to expand – thus opening fissures in rock, making it easier to break
- Heat pumps use the heat of vaporization and heat of condensation of a closed thermodynamic cycle to do useful work.
- Volume expansion during water-to-steam transition
- Superconductivity
- Phase change hand-warmers

Principle 37. Thermal Expansion

A - Use thermal expansion (or contraction) of materials

- Fit a tight joint together by cooling the inner part to contract, heating the outer part to expand, putting the joint together, and returning to equilibrium
- Metal tie-bars used to straighten buckling walls on old buildings
- Thermal switch/cut-out
- Shape memory alloys/polymers
- Shrink-wrapping

B - If thermal expansion is being used, use multiple materials with different coefficients of thermal expansion

- Bi-metallic strips used for thermostats, etc
- Two-way shape memory alloys.
- Passive blade tip clearance control in gas-turbine engines.
- Combine materials with positive and negative thermal expansion coefficients to obtain alloys with zero (or specifically tailored) expansion properites – e.g. cerro-tru alloy used in the mounting and location of fragile turbine blade components during manufacture operations

Principle 38. Strong Oxidants

A - Replace common air with oxygen-enriched air

- Scuba diving with Nitrox or other non-air mixtures for extended endurance
- Use of nitrous oxide injection to provide power boost in high performance engines

B - Replace enriched air with pure oxygen

- Cut at a higher temperature using an oxy-acetylene torch.
- Control oxidation reactions more effectively by reacting in pure oxygen

C - Expose air or oxygen to ionising radiation

- Irradiation of food to improve preservative qualities.
- Use ionised air to destroy bacteria and sterilise food
- Positive ions formed by ionising air can be deflected by magnetic field in order to (e.g.) reduce air resistance over an aerodynamic surface

D - *Use ionised oxygen*

- Speed up chemical reactions by ionising the gas before use.
- Separate oxygen from a mixed gas by ionising the oxygen (using a platinum activator)

E - Replace ozonised (or ionised) oxygen with ozone.

- Oxidisation of metals in bleaching solutions to reduce cost relative to hydrogen peroxide
- Use ozone to destroy micro-organisms and toxins in corn
- Ozone dissolved in water used to remove organic contaminants from ship hulls

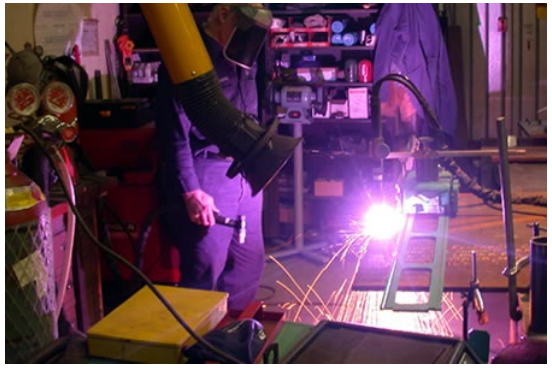
Principle 39. Inert Atmosphere

A - Replace a normal environment with an inert one

- Prevent degradation of a hot metal filament by using an argon atmosphere.
- MIG/TIG welding
- Electron beam welding conducted in a vacuum
- Vacuum packaging
- Food packaging done in CO_2 or nitrogen rich atmosphere to prevent spoilage
- CO_2 fire extinguisher

B - Add neutral parts, or inert additives to an object

- Naval aviation fuel contains additives to alter flash-point.
- Add fire retardant elements to titanium to reduce possibility of titanium fire.
- Add foam to absorb sound vibrations – e.g. hi-fi speakers
- Fluidic dampers



Principle 40. Composite Materials

A - Change from uniform to composite (multiple) materials where each material is tuned to a particular functional requirement

- Aircraft structures where low weight and high strength are required. (With fibres aligned according to loading conditions – including multiple layers of fibres aligned in different directions.)
- Composite golf club shaft aligns structures to give low weight, high shaft-wise flexibility and high torsional stiffness.
- Concrete aggregate.
- Glass-reinforced plastic
- Fibre-reinforced ceramics
- Hard/soft/hard multi-layer coatings to improve erosion, etc properties.
- Non-stick coatings on cooking pans.
- Oils, etc contain additives to improve certain properties – e.g. sulphur improves lubricity