TRIZ for Systematic Innovation

Level 1 MATRIZ Official Certification

Need for systematic Innovation

Problem

- The following was the process for the manufacture of Chrome plated rulers. The rulers we made of high carbon steel and etched to have the graduations.
- After the graduations are etched the rulers were chrome plated as that gives the rulers a rich matte look and also wear resistant. In order to make the graduations visible Paint was applied over the entire surface. That way the paint would get into the graduations and also would remain on the surface.
- The rulers were then placed in an oven and baked at 100 degree centigrade for the curing of the paint, post which the rules were cooled and held under running water and workers would then use a charcoal piece and under running water rub the blank.
- The paint would remain in the graduation that was etched and would slowly come out from the other areas due to the friction being applied, However many time paint would also come out from the graduations and the process would have to be repeated. This was time consuming also it was possible that the paint would come out later when the customer was using the same this lead to complaints,
- What to do to resolve the problem at hand

Sauce Fungus

- When Sauce is manufactured , it is poured in the bottles when it is hot, As the temperature is high the speed of pouring is good and also the bacteria dies, hence there is no need to have a process for the removal of bacteria, post which it is capped. however after manufacturing there were numerous complaints of fungus observed in the bottles what must be done

Conventional Approach is Inefficient

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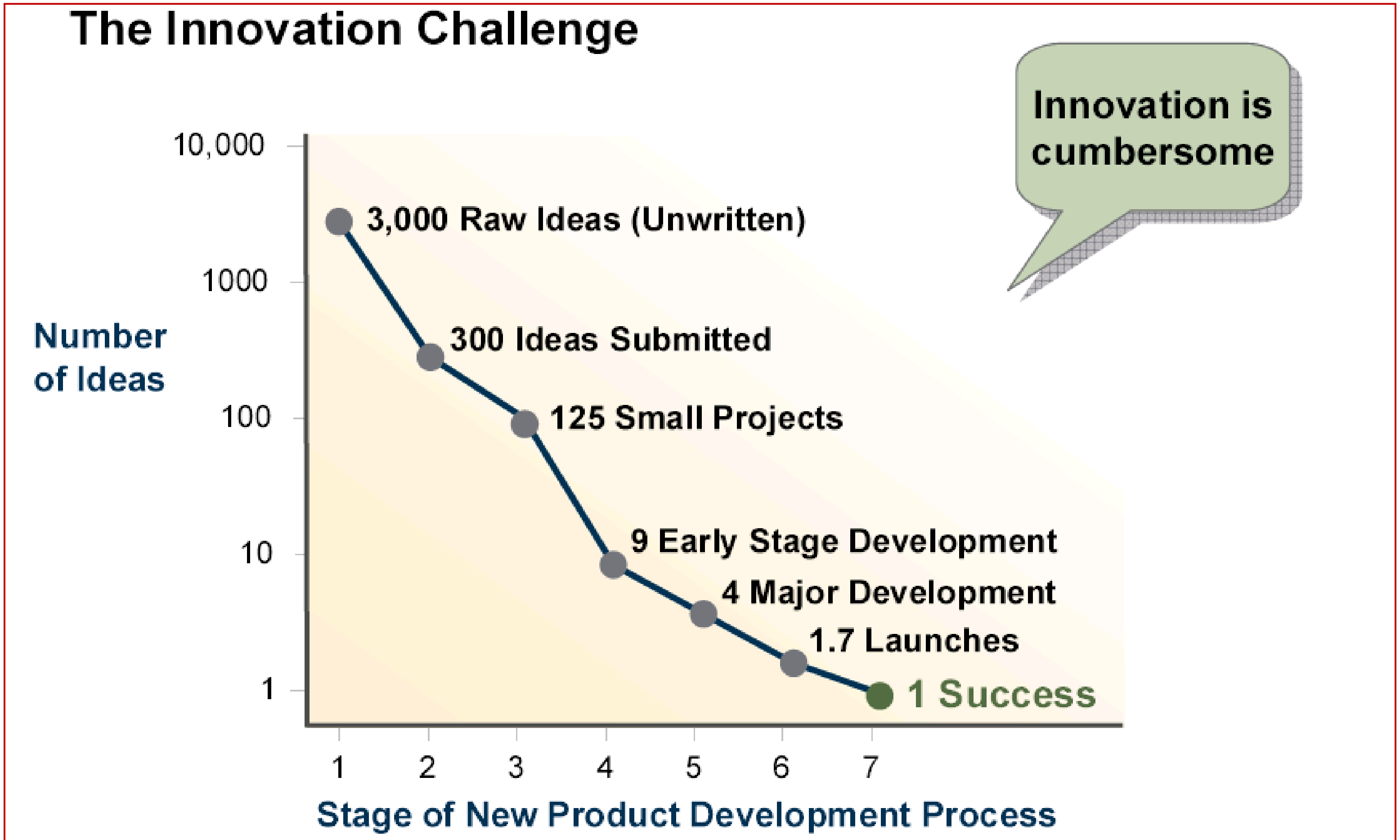
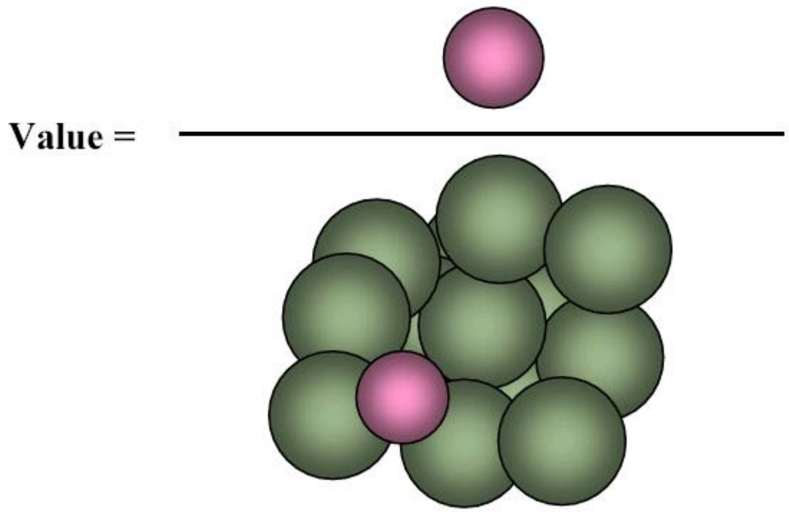
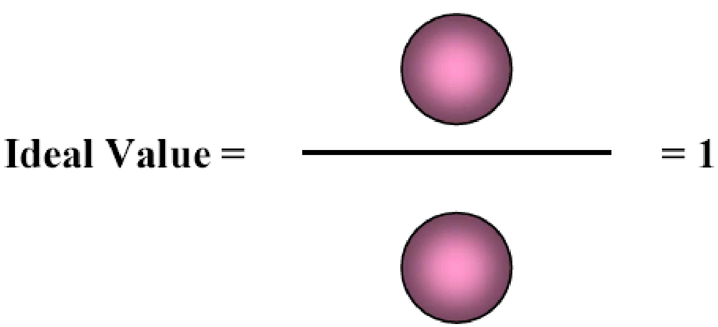
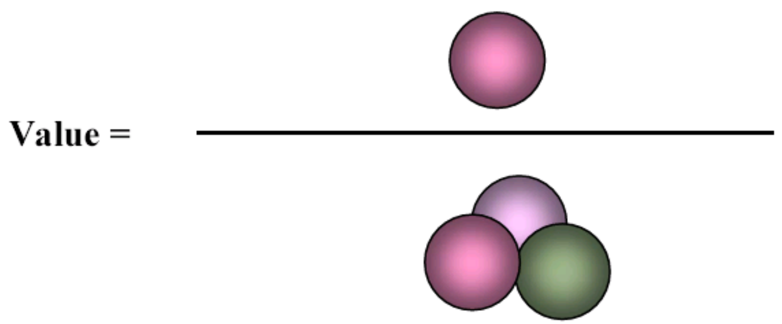


Source: G. Stevens and J. Burley, "3,000 Raw Ideas = 1 Commercial Success!" *Research•Technology Management*, 40(3): 16-27, May-June, 1997.

Innovation Value







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…The problems that exist in the world today

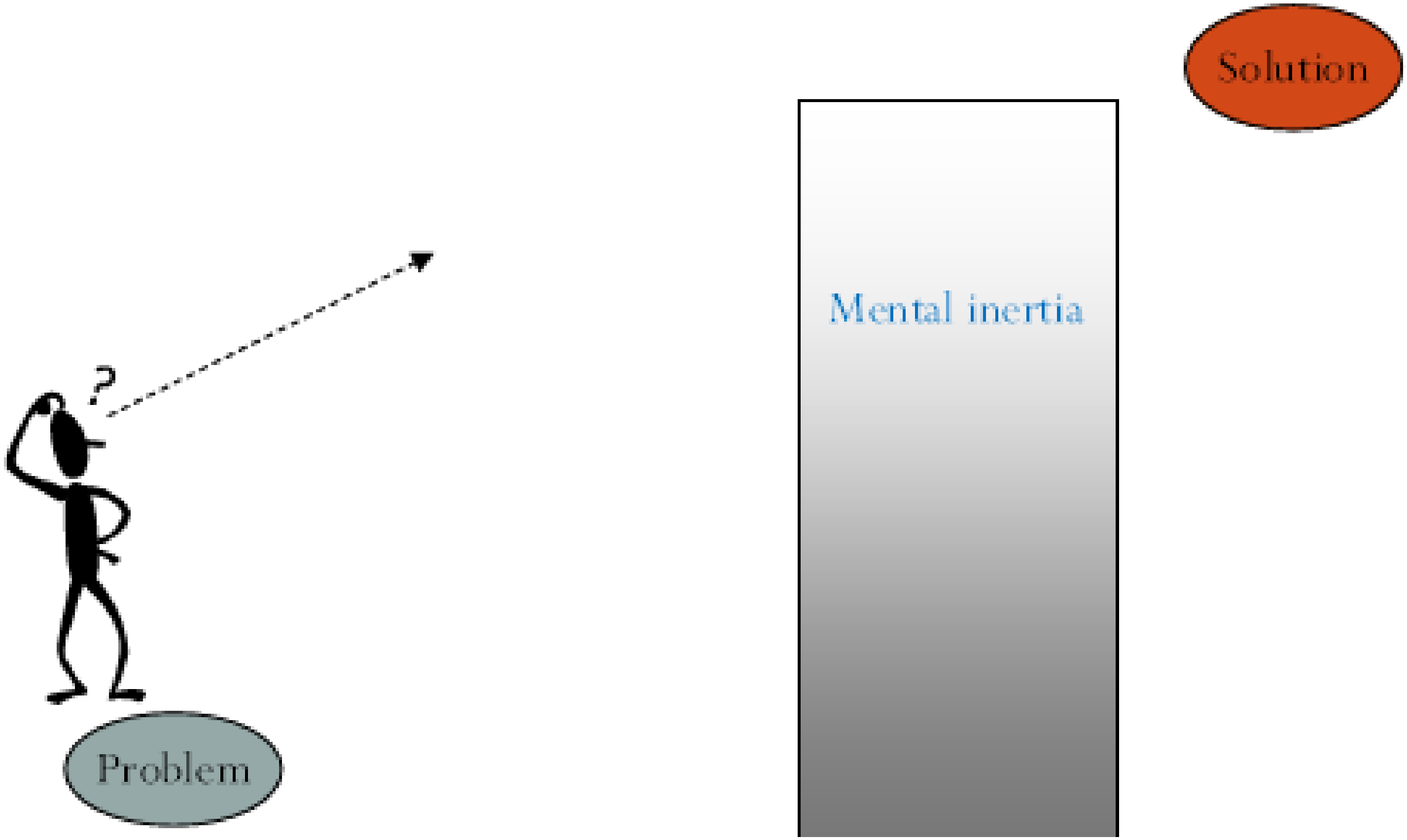
cannot be solved

by the level of thinking

that created them...

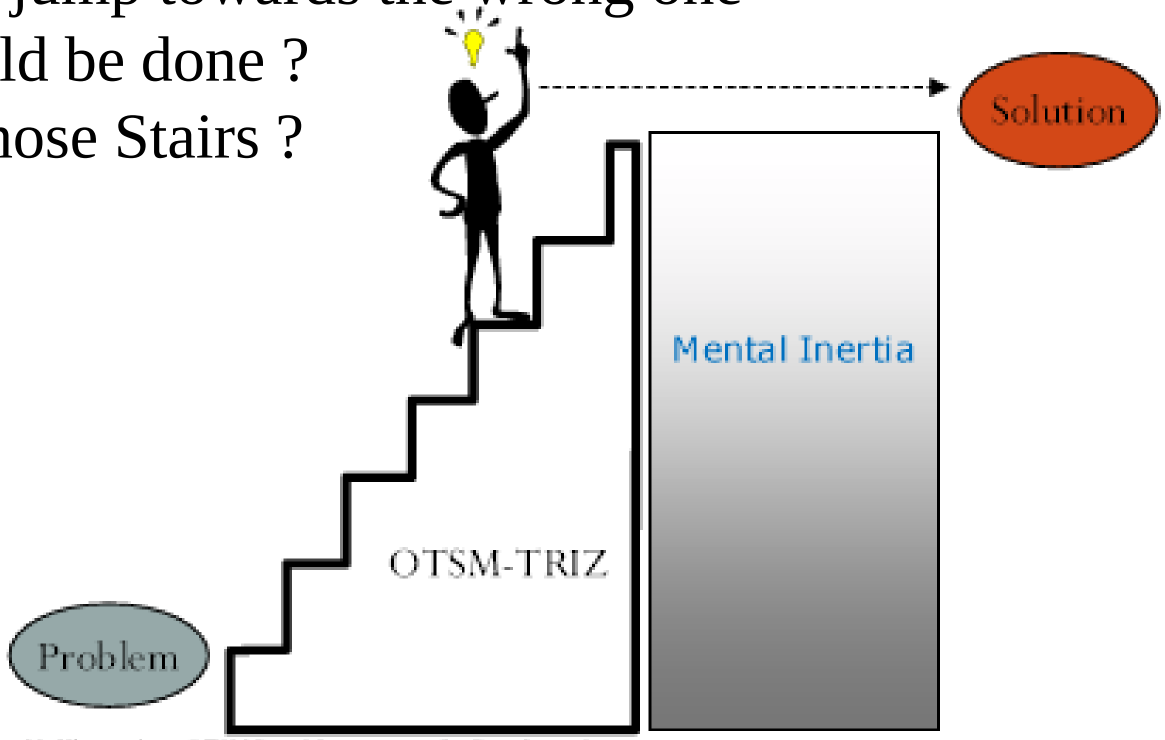
attributed to Albert Einstein

How do we solve problems

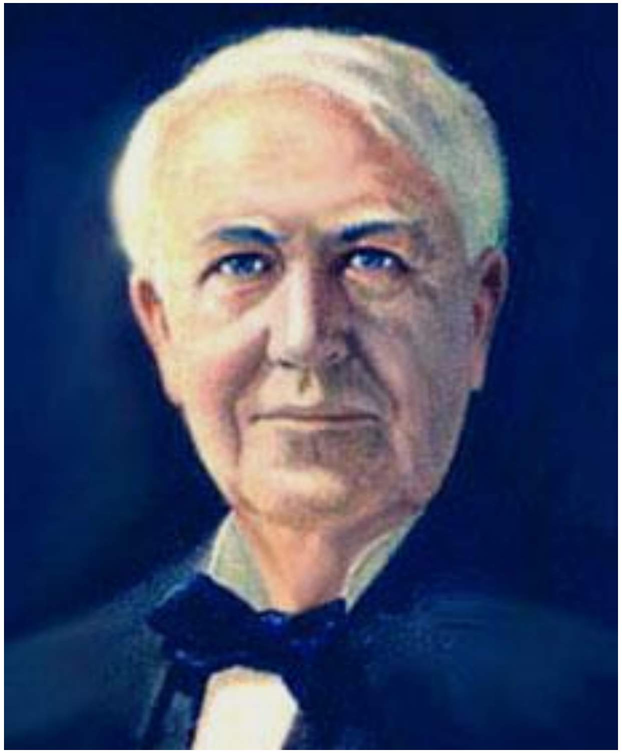


How TRIZ helps us solve problems

TRIZ provides us with Stairs:
It is easy and useful to overcome mental inertia doing small steps towards right direction, than make a big jump towards the wrong one
How it could be done ?
What are those Stairs ?



The Great Inventor Thomas Edison



THOMAS EDISON
Inventor
1076 Patents
* Electric vote recorder
* Stock ticker
* Quadraplex telegraph
* Phonograph
* Light-bulb
* Electrical distribution system
* Motion picture camera
* Fluoroscope
* Dictating machine
* Telephone

"Genius is 1% inspiration and 99% perspiration."

Carbon Light-bulb Filament - 6,000+ experiments

Nickel/Iron Battery - 10,296 experiments

Edison's success Inspired the Innovation Industry

- Many organizations in that era impressed with Edison's recipe for innovation set up giant R&D labs manned by thousands of technicians adopting Edison's philosophy of carrying out thousands of simultaneous trials in the hope of discovering a new phenomenon.

Edison and the Perils of Psychological Inertia

Nikolai Tesla

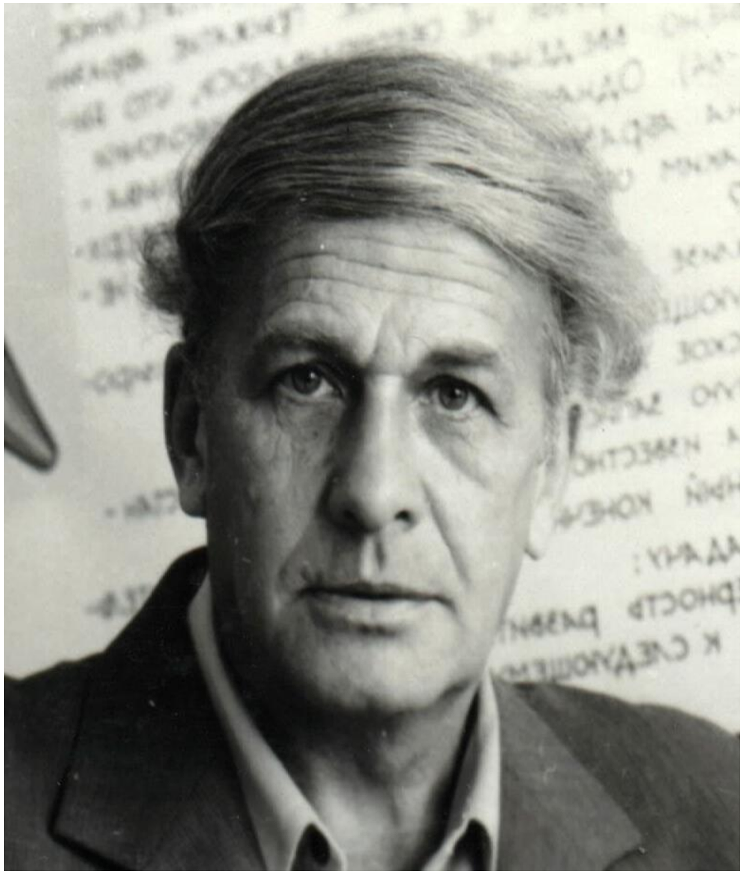
- *"If Edison had the task to find a needle in a haystack he would not lose time determining the most probable location of it.*
- *He would immediately with the diligence of a bee begin picking up straw after straw until he found the object of his search.*
- *His methods were very inefficient. He would spend a lot of time and energy reaching nothing unless luck was with him in the beginning.*
- *It was sad watching him work knowing that just a little theoretical knowledge and a few calculations could save him at least 30 per cent of his time.*
- *He despised education from books and especially the knowledge of mathematics trusting completely to his inventive intuition and American commonsense."*

Edison and the Perils of Psychological Inertia (cont)

- Edison’s expensive and wasteful approach soon became evident to the organizations supporting those giant R&D labs and these were soon replaced with efficient and productive ways.
- In today's world we cannot afford to have Edison’s trial-and-error kind of a strategy for trying to come out with innovations
- Unfortunately, many organizations still persist with the trial-and-error approach to problem solving

TRIZ, the Theory of the Solution of Inventive Problems

- Russian acronym for the Theory of Inventive Problem Solving originated in 1946 by Genrich Altshuller
- Systematic, structured way of thinking
- Science of technological evolution
- Results of analysis of over 2 million worldwide patents within all engineering disciplines



Genrich Saulovich Altshuller
10/15/26 to 9/24/98

Provokes Inventions At Lower Levels

Helps Solving

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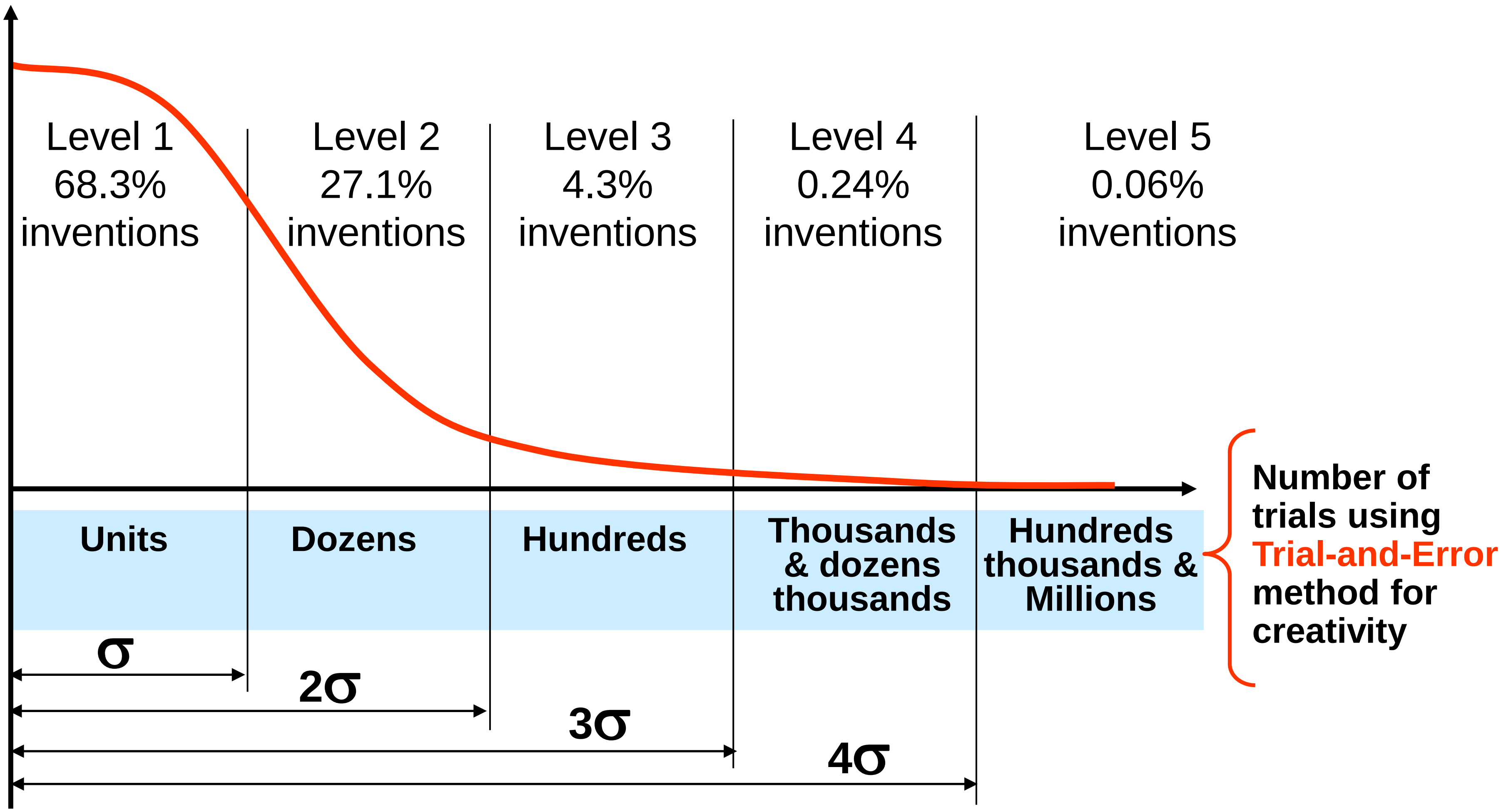
	Level of Innovation	1	2	3	4	5
		Apparent / Conventional Solution 32% (1964-1974) *(trivial non-inventive inv.)*	**Small Invention Inside Paradigm** 45% (1964-1974) *(common invention)*	**Substantial Invention Inside Technology** 18% (1964-1974) ***(average, solid invention)***	**Invention Outside Technology** 4% (1964- 1974) ***(macro inventions)***	**Discovery** 1% (1964– 1974) *(major invention & new science)*
A	**# of Attempts**	No more than 10	$10 – 10^2$	$10^2 – 10^3$	$10^3 – 10^4$	10^5 / lifetime dedication
B	**Field of Solution**	Problem & solution methods **within one professional field**		Problem & solution methods belong to **same technology**	Other science field, **outside technology** involving completely different principle	**Outside** contemporary **scientific knowledge**
C	**Solution Mechanism**	**Obvious** (undisguised) solutions from a few clear options	Solution **not obvious** to untrained person – possible give-up	Technology of other industries **beyond accepted ideas & principles** ⇨ paradigm shift in industry	**New generation of design** using science not technology	**New phenomenon** discovered & applied to inventive problem
D	**Characteristics of System**	**Existing system** not substantially changed	**Existing system** slightly changed	**Existing system** essentially improved	Synthesis of **a new technical system**	**New technical systems**, industries & design products
E	**Effects / principles leading to solution**	Enhanced features - **good engineering**	**New features** ⇨ improvements, but obvious compromise	Combination of several physical effects, 'tricky' methods, **ingenious use of well-known physical phenomena**	**Physical effects & phenomena previously little known**	Solution methods **beyond the scope of modern science**
F	**Existence of Contradictions**	Contradictions **not identified & resolved**	System inherent contradiction **reduced, but not eliminated**	Contradiction **resolved within existing system**, often through introduction of entirely new element	Contradictions **eliminated since non-existent** in NEW system	**No** contradictions
	Examples	Increasing wall thickness to create greater insulation	Adjustable steering columns increases range of body types able to drive comfortably	Replacing standard transmission of a car with an automatic transmission	Using material with thermal memory for key rings that open in hot water	Laser, Transistor

[Yuri Salamatov "TRIZ: The Right Solution at the Right Time", Insytec B.V., The Netherlands, 1999, ISBN 90-804680-1-0]
[John Terninko, Alla Zusman, Boris Zlotin. "STEP-by-STEP TRIZ: Creative Innovative Solution Concepts" Resp. Mgmt Inc., Nottingham, NH, USA, 1996]

Levels of Invention



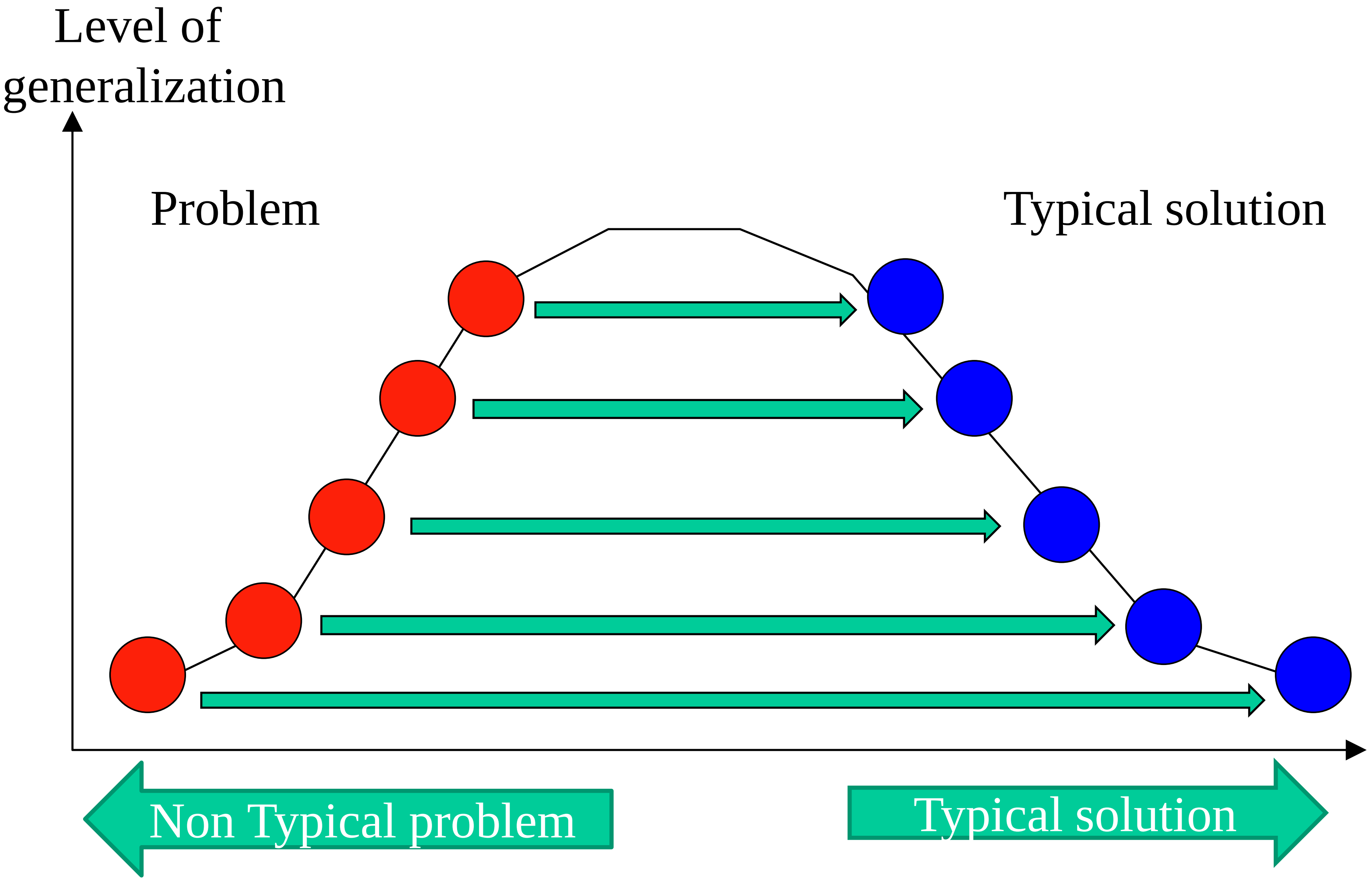
Everyone can be a problem solver

- All people are creative and have something to contribute
- Approach the problem positively, with tolerance for the views of others
- Reserve judgment until all the facts are gathered
- Engender an environment that promotes idea generation
- Work from the strengths of each individual

Kings problem

- Once upon a time there was a country whose old king died. The king who replaced him, right away wanted to show people how kind and trustworthy he is, and the first thing he decided to do was to give all the inmates the in country’s prisons a half amnesty. All the prison terms were to become two times shorter. there However, appeared a difficulty that the king hadn’t noticed before. What about those inmates life who had life—time sentences? What was he to do with them?

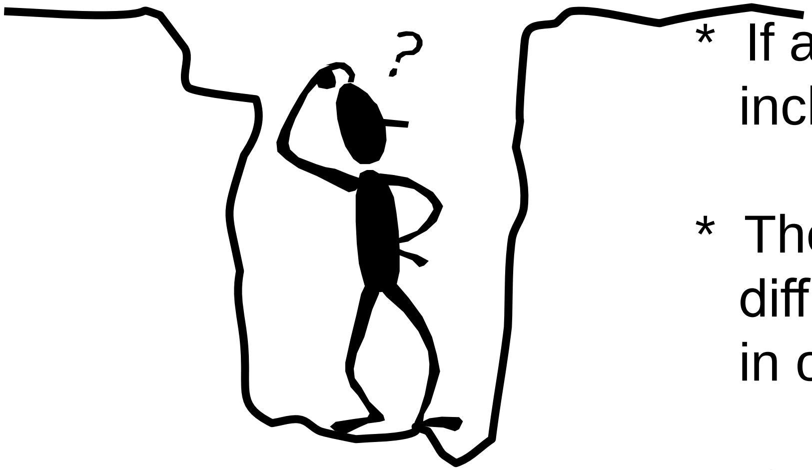
Abstraction model



TRIZ based Advanced Thinking

- Ability to see links between phenomena and objects
- The ability to pick up the sore point , the core of the problem
- Ability to identify and formulate contradictions
- Ability to consider each object in evolution (past, present and future)

Psychological Inertia



* Problem solving is like digging for treasure in a field

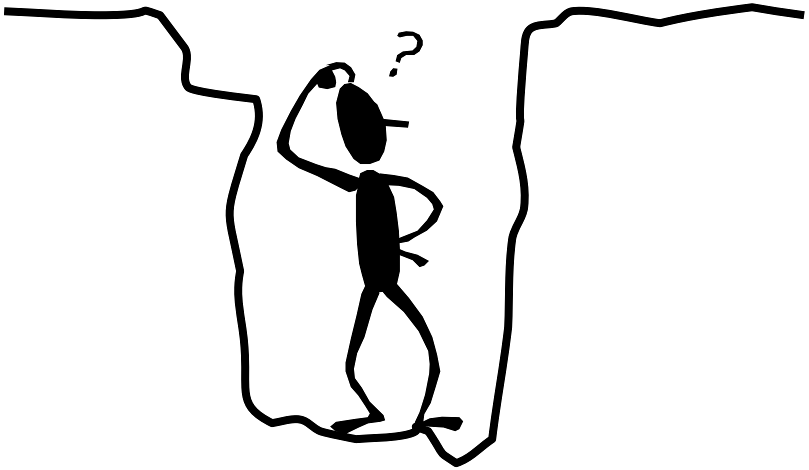
* If a hole already exists, our inclination is to dig it deeper

* The deeper the hole, the more difficult it is to see what’s happening in other parts of the field

* If someone else comes along, we encourage them to jump in the hole with us

* The overall effect is called PSYCHOLOGICAL INERTIA

Psychological Inertia



Let us assume that 300 electrons in different groups, must jump from one energetic level to the other.

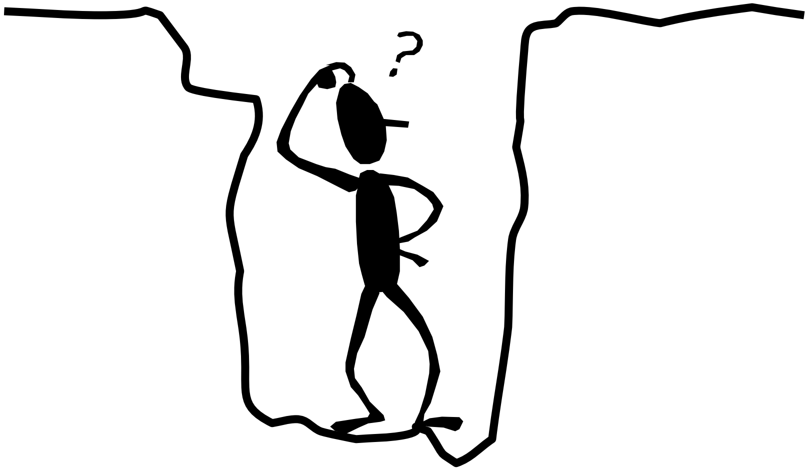
However a quantum transfer has already taken place by two groups less than were originally calculated;

consequently each group now has five more electrons,

how many electron groups were there in total?

This complex problem is not solved as yet

Psychological Inertia



To send 300 scouts to a summer camp, several buses were reserved; however two buses did not show up at the required time ,

therefore each bus took 5 scouts more than was planned , how many buses were sent

16 Types of Psychological Inertia

- Terminological Inertia
- Image Inertia
- Inertia due to functional orientation

To solve problems the problem solver has to overcome the minimum three

Keys to break psychological inertia

- Ability to see links between phenomena and objects
- Ability to analogically think
- Ability to Fantasize

Analogy and Problem solving

- All thought draws on Knowledge we already possess
- The components of knowledge can be regarded as mental representations which are analogical or symbolic
- An important example of analogical representation in thinking is provided by mental images
- Problem solving is not always successful
  - One reason is Psychological inertia
  - Absence of developed analogical thinking
  - Absence of appropriate restructuring problems

Exercise

- We will break the class into two groups
- One group will be given the tumor case study
- The other group will first receive a story to read on how a fortress was captured
- After reading and comprehending the story the group will attempt solving the Tumor problem
- Readouts and Discussions

how to protect a hydrofoil moving at a high speed from hydraulic cavitations, which results from collapsing air bubbles which destroy the metal surface of the foil? And the second problem:

how to prevent orange plantations from being eaten by monkeys if installing fences around the plantations would be too expensive?

Is there any similarity in the two problems?

Analogy

Analogy, a relationship of similarity or likeness between two or more entities. For example, an analogy, or similarity, between the human heart and a mechanical pump has been argued.

"Analogy," Microsoft® Encarta® Encyclopedia 2000.

Analogy – example or illustration, suggested with software, which we use as an ideas source for improve given system

Analogy problem – problem, somehow or other similar to given problem

Analogy solution – idea of solution of analogy problem, possible useful for solution of given problem

The method of Focal Objects

- The method was first proposed to by A.Kuntze a professor of the Berlin University as a method of the catalogue

- It was proposed to open any catalogue (the dictionary, the book, magazine) to choose any word and "to join" with initial word (the name of the prototype).
  - For example, if the prototype "milling cutter" and a casual word is "snow" than the combination "a snow milling cutter" has appeared.
  - This combination can be developed, using associations: ice milling cutter, a cold cutter, a slippery cutter etc.

- In the past 50 years the method was advanced by Charls.Vatingem (USA) and has received the name **<u>as method of focal objects</u> (MFO).**

Procedure for using method of focal objects

1. Choose the object that is necessary to improve
   - This object is called, the Focal Object
2. Formulate the purpose of perfection of the object.
   - Objective that we would like to set forward for enhancement, improvement, or creation
3. Choose casual words or objects with the help of any book, the dictionary or any other source.
4. Define the properties of the chosen casual objects.
5. Transfer the defined properties on to focal object.
6. Write down ideas received from a combination of focal object to properties of casual objects.
   - Using imagination you should develop the received ideas in new invention and present as figures, schemes.
7. Carry out the analysis of the received combinations and to choose the most suitable.

Example: Inventing a Book

- For example, it is necessary to invent a new book, with new properties for increasing the amount of books sold.
  1. Let's take the object, the normal book.
  2. Let's define the purpose of perfection.
     – To improve the appearance of the book for increasing the sales
  3. We shall choose 3 casual objects:
     - a bulb;
     - a TV;
     - a calculator.
  4. We shall define 2 properties for each of 3 objects.
     – Bulb, what are the two properties? It shines and heats.
     - TV, what are the two properties? It shows, speaks.
     - Calculator, what are the two properties? It calculates, multiplies.

Example (cont)

5. Mentally we shall transfer functions of each of 3 objects on the book. What book do we get?
   - The book shines.
     - What does it mean? Let's imagine and dream. We get an idea:
       - The letters of the book shine
     - Where it is necessary to have such a property for the letters of the book?
       - At night? Quite right.
     - The book which is possible to read at night without light was invented.
     - Is this useful invention?
   - Further, the book which heats. We imagine again and get another idea:
     - Book with a heating element.
     - Where it can be applied?

Example (cont)

5. Mentally we shall transfer functions of each of 3 objects on the book. What book do we get? (cont)
   - The talking book.
     - What makes this book special? It tells itself.
     - For what purpose it is necessary? Can it tell fairy tales to children? Is this useful invention?
     - Existing example: the congratulatory picture post card consisting of two sheets. On opening we obtain melodious sounds.
   - The book which shows as the TV.
     - What makes this book special?
     - For what purpose it is necessary?
     - The book is like a TV (a computer, notebook computer).
     - Here it is possible to invent many different variants.
     - It can look as a separate sheet which has a screen.
     - On the screen there is a text of any book, speed of the text can be adjusted, can be showed various pictures, etc.
     - Is this useful invention?

Example (cont)

5. Mentally we shall transfer functions of each of 3 objects on the book. What book do we get? (cont)
   - The book which can calculate and multiply.
     - What makes this book special?
     - For what purpose is it necessary?
     - For example, the book-calculator.
       - On back page the calculator is built in.
     - Is this useful invention?
       - Certainly it is, for schoolboys.

Example (cont)

- All invented solutions can be written in the form of a table.

Focal object is book		**The purpose of improvement is to invent the book with new properties.**	
Casual objects	**Properties of casual objects**	**Focal object + properties**	**Invented ideas**
Bulb	gives some light for heats	1.The book gives light for. 2. The book heats	1.The book with the light or with the letters which can give light. 2.The book-heater.
TV-set	can show can speak	1.The book, which shows. 2. The book, which speaks.	1.The book-TV set. 2. Speaking book.
Calculator	calculates multiplies	1.The book, which calculates, multiplies.	1.The book-calculator.

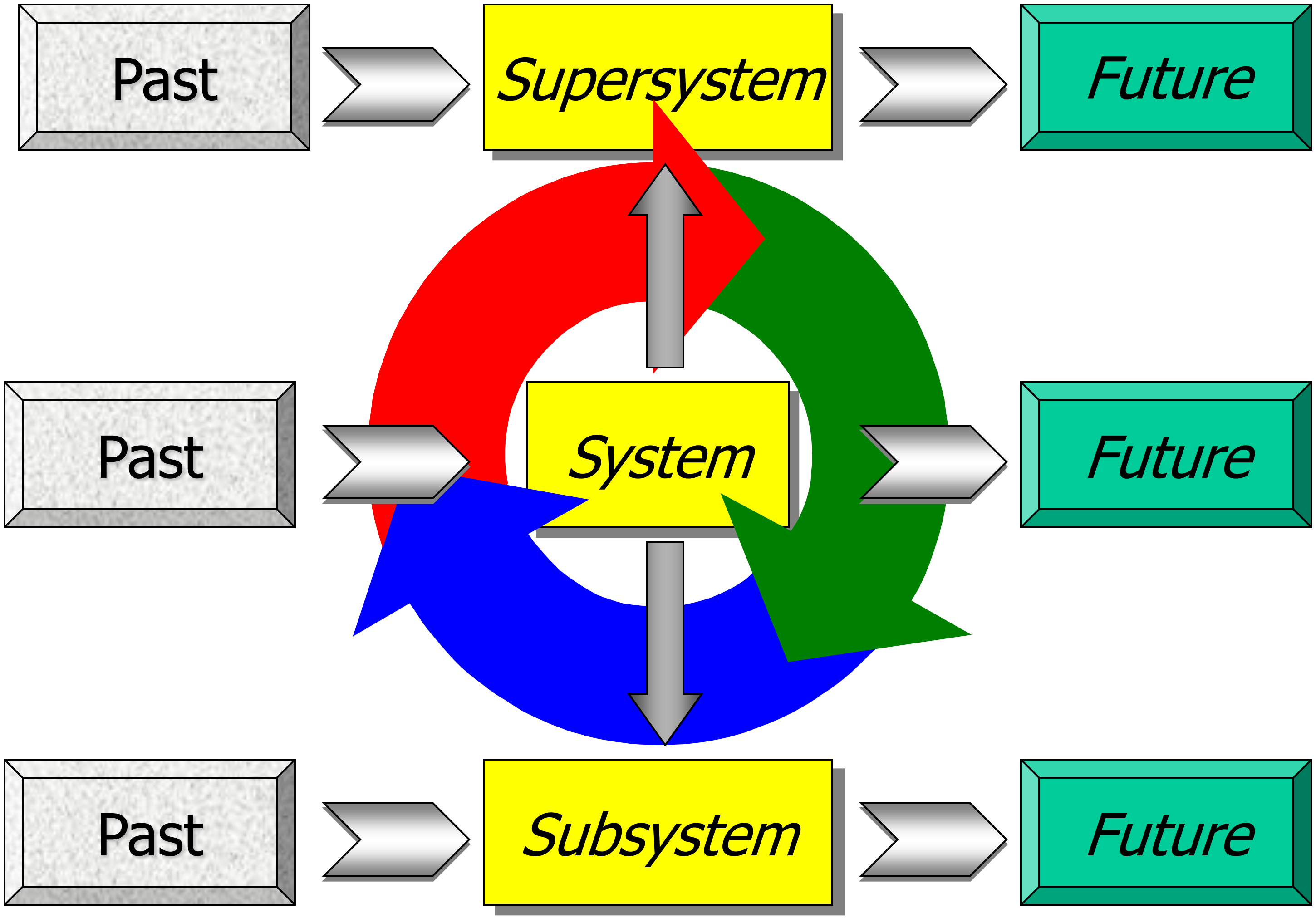
Exercise

- Create focal object table between a mobile phone and a shoe and based on the analogy table using Focal objects come up with creative ideas to design a better shoe

System Operator

- To make an invention a problem solver should be able to
  - See a potential system in a group of separate , uncoordinated elements that represent subsystem
  - Develop certain links between subsystems that can create a new and useful property
  - Understand the super system of the system under consideration
  - Know limits on changes in the system and super system
  - Have knowledge about the anti function, co system and non systems
  - Be familiar with previous developments of the system, super system and the subsystem
  - Have knowledge about the anti functions , super functions and non functions
  - Be informed about the next future forecast of the system

System Operator Multi Screen



The system operator algorithm for technical objects

1. Choose TS (put it into the middle screen, axis of present).
2. Define subsystems of the given TS (put them in the screen subsystem, axis of present).
3. Define supersystems (one or several) of the given TS (put them in the screen supersystem, axis of present).
4. Define prototypes of TS, what TS preceded (put it in the screen system, axis of past).
5. Define subsystems of TS prototype (put them in the screen subsystem, axis of past).
6. Define supersystem (one or several) for TS prototype (put them in the screen supersystem, axis of past).
7. Formulate HE (harmful effect), TC, that TS underwent at transition from past to the future.
8. Manifest and formulate HE (harmful effect) and TC for TS in the present.
9. If the system doesn't exist, then one can create a new TS with the solved TC (put it in the screen system, axis of future) using imagination and manifested HE (harmful effect).
10. Using imagination manifest subsystems of new TS (put them in the screen subsystem, axis of future).
11. Using imagination manifest supersystems of new TS (put it in the screen supersystem, axis of future).
12. Make a draft of new TS. Answer the questions due to what will the MUF be fulfilled now? What are the TCs of TS now?

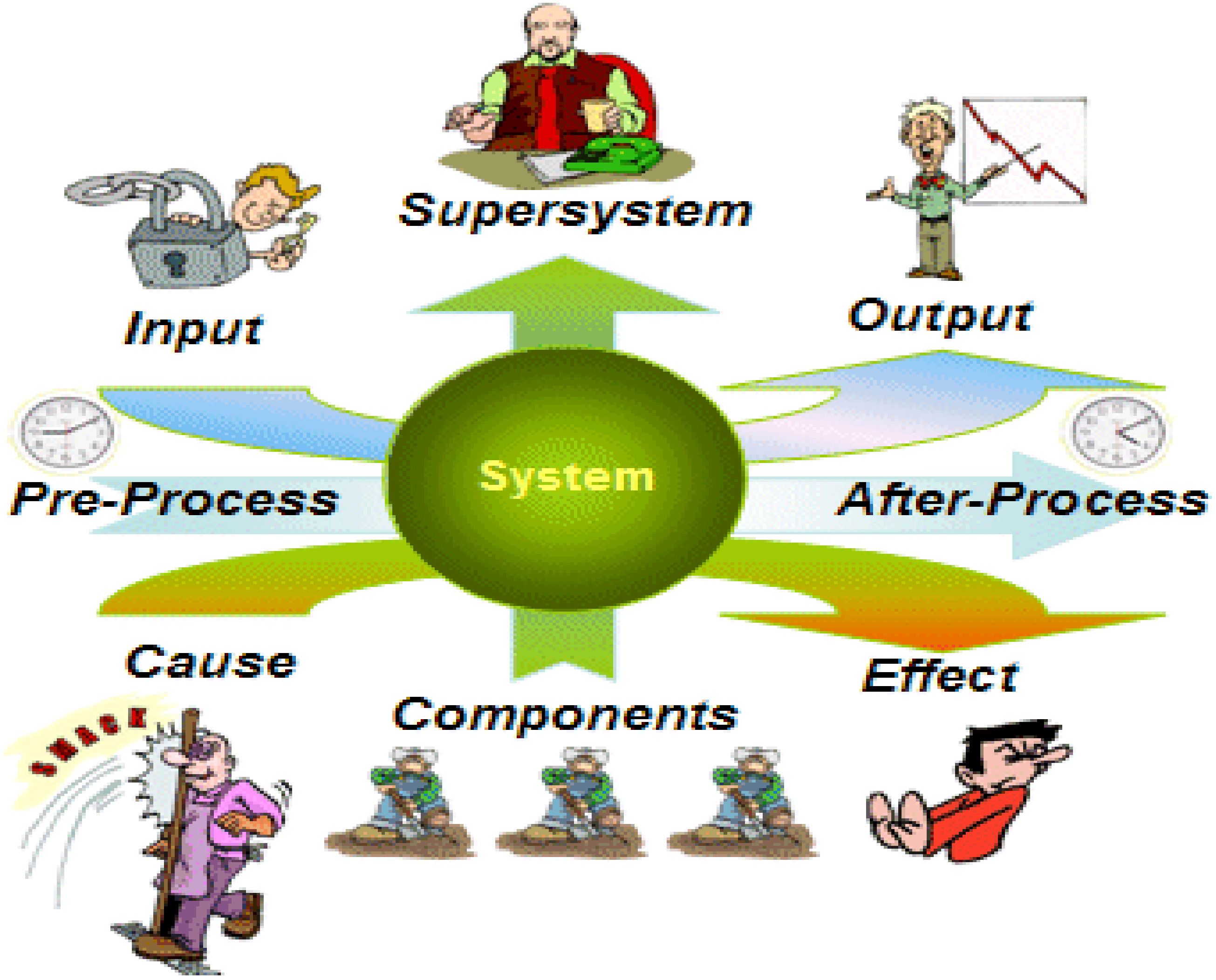
Example of System operator

Super-System Past Doves Horse rider	**Super-System** airmail	**Super-System Future** Electronic mail. Speed is significantly higher
System Past A scroll tied with a string with a seal, a bottle, Clay slates (Low speed, low probability that post will reach the destination)	**System** Letter (Low speed, the envelope can be lost.)	**System Future** 1. Computer letter (envelope is of no use)
Sub-System Past A sheet of low-quality paper glass wood	**Sub-System** A sheet of paper envelope ink.	**Sub-System Future** bytes of information in the computer fixed disc

System Operator

- The system operator can also be built for an
  - anti System (a system with opposite primary functions or properties, instead of heating it would cool, instead of mixing it would divide, instead of being heavy it would be light)
  - A concurrent or alternate System , often also called as co system (a system with complementary functions or properties, example when studying a car the alternate systems can be Trucks, two wheelers)
  - A Non system (a system with the same primary functions or properties, example when studying a car a non system can be Trains , Aero planes, cable cars, etc)

Scheme for problem definition using System operator



System operator Window - System

- For the System dimension you have to answer the following
  1. What is the “system”?
  2. What primary function does the system perform?
  3. What problem are we trying to solve?
  4. What changes in the system (etc.) might improve the solution? Is it possible to improve the system to the extent that the drawback becomes insignificant or at least tolerable?
  5. Is there another system (Alternate System) that can be improved in order to obtain the desired result? Would shifting to some other “principle of operation” prevent the drawback from occurring, or significantly reduce or weaken it?
  6. What is the anti system, what problems were faced by the anti system and how did they resolve them? Can some of those principles be used?
  7. Have similar problems occurred previously in other systems or other places? If Yes, then
     - How were they addressed?
     - Why won’t the earlier solutions work now?
     - Is it possible to modify a solution to make it useful for the situation you are now faced with?

System operator Window - Super-System

- For this dimension you have to answer the following
  1. Describe the super-system to which your system belongs. Consider
     - Other parts of the super-system
     - Other systems near the super-system or those that might be located nearby
     - Other systems interacting with the system and its super-system, especially sources of people, information, energy etc
     - Conditions around the system and its super-system, both artificial and natural (social and psychological environment, indoor and outdoor conditions, etc.)
     - Requirements for interaction between the system/super-system and the environment mentioned above
  2. What elements from the environment might eliminate the problem altogether, or at least reduce its severity?
  3. From what other super-system (Alternate or Anti) can the desired result be obtained?

System operator Window - Sub System

- For this dimension you have to answer the following
  1. Describe the system's structure in its static state (i.e. when not operating).
     - Indicate all sub-systems, important elements, and connections between them. If necessary, develop a separate sketch or layout of the system in detail
  2. Regard the structure of the system, Anti System. Alternate System, as a resource for problem solving.
     - How can modifying the system structure influence the problem – perhaps some structural changes can eliminate the problem altogether, or at least reduce its severity?
  3. Describe the functioning of the system in its dynamic state.
     - List the functions for each of the sub-systems and describe the connections between them.

System operator Window - Inputs

- For this dimension you have to answer the following
    1. What enters the system (substances, energy, information, etc.)? Describe all inputs to the system.
    2. How does the input become an output?
    3. How can you change an input to improve the situation?

System operator Window - Outputs

- For this dimension you have to answer the following
  1. What outputs are created by the system
  2. Describe all the outputs and consider them as resources. How can you influence an output to improve the situation?

System operator Window - Cause

- For this dimension you have to answer the following
  1. What is the cause of the problem?
  2. How is the cause transformed into the effect?
  3. Describe all known causes and critical conditions of the problem. What changes would eliminate the cause?

System operator Window - Effect

- For this dimension you have to answer the following
  1. Describe all known hypotheses (mechanisms) regarding the cause of this problem using "cause-and-effect" chains
  2. What will be the consequences if this situation is not improved?
  3. Is there another way to avoid these consequences?
  4. How can you influence an effect?

System operator Window - Preprocess

- For this dimension you have to answer the following
  1. How long ago did the situation emerge?
  2. Was this emergence associated with a specific event, such as change to the system, technology, strategy, environment, etc?
  3. Is it possible to “go back” to this event and change the outcome?
  4. What events happened before process?
  5. How can you change the critical events?
  6. Describe all previous attempts to solve the problem, and explain why they didn’t work
  7. Can we implement a “future” solution today?

System operator Window - Post process

- For this dimension you have to answer the following
    1. What is the after-process of your system?
    2. Describe the post-process time intervals. How can you utilize post-process?

Example

- During the Second World War, fires aboard aircraft often occurred when the fuel tanks were hit by bullets. This was the case only if a fuel tank was not full -- that is, if it was partially filled with fuel vapors. What must be done?

Applying Systems thinking

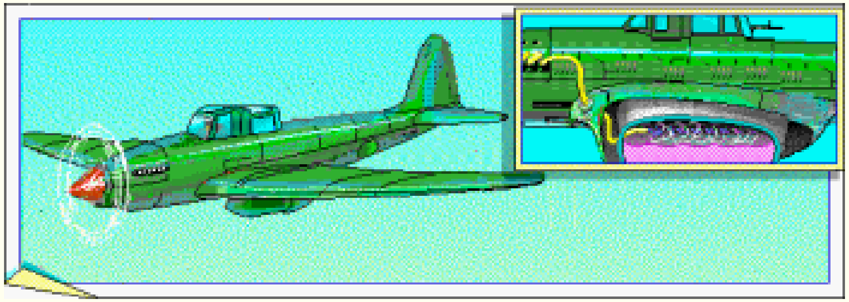
- System dimension
  1. What is the “system”?
     1. The System is the fuel tank (Notice we are focusing on the problem area as the system)
  2. What primary function does the system perform?
     1. The primary function of the tank is to store fuel so that the fuel can be later used to generate power
  3. What problem are we trying to solve?
     1. When the tank is pierced and it is partially full the vapors of the fuel tend to catch fire thus making a hazard to the airplane
  4. What changes in the system (etc.) might improve the solution? Is it possible to improve the system to the extent that the drawback becomes insignificant or at least tolerable?
     1. If the tank would not get hit, If the tank is bullet resistant, If he tank is self repaired and the fuel does not leak
  5. Is there another system (Alternate System) that can be improved in order to obtain the desired result? Would shifting to some other “principle of operation” prevent the drawback from occurring, or significantly reduce or weaken it?
     1. The alternate systems can be fire resistant systems or breakage proof containers or self repairing containers
     2. The primary principle of fire resistant systems is deprive fire zone of oxygen,
     3. The primary principle for breakage proof containers is offering penetration resistance by increasing wall thickness
     4. The primary principle of self repairing tank would be immediately seal the hole caused by the bullet.
  6. What is the anti system, what problems were faced by the anti system and how did they resolve them? Can some of those principles be used?
     1. The Anti system in this case will be producing explosion
     2. To provide strong explosions we supply the explosion zone with Oxidizers
  7. Have similar problems occurred previously in other systems or other places? If Yes, then
     - How were they addressed?
     - Why won’t the earlier solutions work now?
     - Is it possible to modify a solution to make it useful for the situation you are now faced with?
       1. Is the problem now how to deprive the leakage zone from oxygen so that there will be no fire?

Applying Systems thinking

- Super System Dimension
  1. Describe the super-system to which your system belongs. Consider
     - Other parts of the super-system
     - Other systems near the super-system or those that might be located nearby
     - Other systems interacting with the system and its super-system, especially sources of people, information, energy etc
     - Conditions around the system and its super-system, both artificial and natural (social and psychological environment, indoor and outdoor conditions, etc.)
     - Requirements for interaction between the system/super-system and the environment mentioned above
     1. The airplane, the pilot, the combustion chambers, the exhaust, the bullet, the atmosphere, etc
  2. What elements from the environment might eliminate the problem altogether, or at least reduce its severity?
     1. Idea: What we need is a method of how to eliminate oxygen from the region where the bullet strikes the tank so that there will be no combustion, this can be provided by the exhaust of the air plane as the exhaust contains carbon dioxide that will ensure that there will be no fire, so pass the exhaust gases in such a manner over the tank surface.
  3. From what other super-system (Alternate or Anti) can the desired result be obtained?

Solution Deployed

Fireproof Aircraft Fuel Tank



During the Second World War, fires aboard aircraft often occurred when the fuel tanks were hit by bullets. This was the case only if a fuel tank was not full -- that is, if it was partially filled with fuel vapors.

To take advantage of this, exhaust gases can be blown through a fuel tank to prevent the fuel vapors from igniting. Because the exhaust gases do not contain oxygen, the fuel will not burn even if the fuel tank is hit by a bullet.

Summary

- The inventor should remember the following:
- World is systematic and consists of several ranges of super and subsystems.
- Every system is connected with each other. Changes in one of them lead to changes in all the rest.
- Inventive thinking includes at least 9 screens in the past, present and future.
- At solving inventive problems one should think globally, covering al the systems in space and time and work locally with minimal expenses of the same time and place.

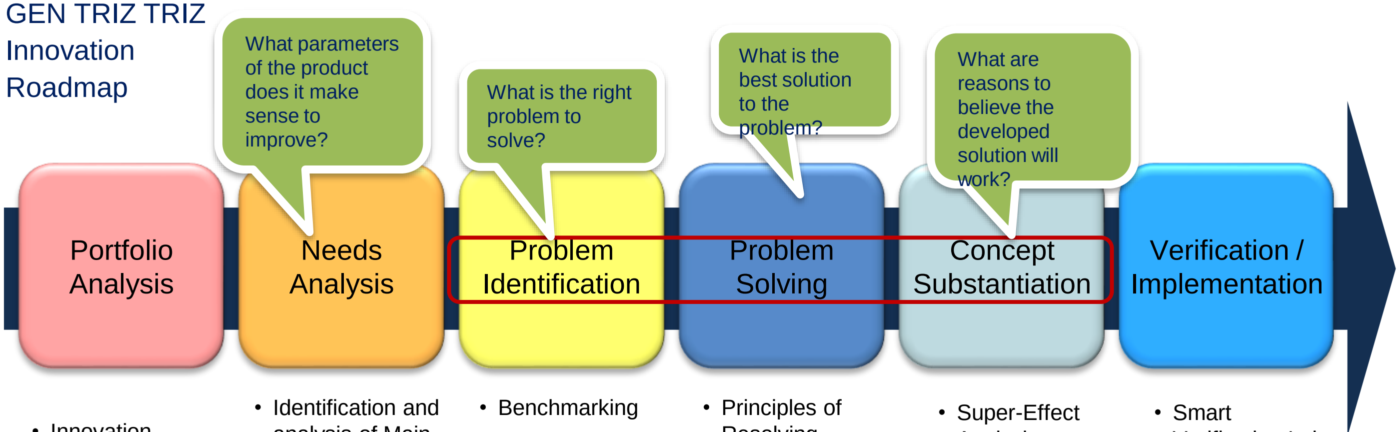
Exercise

- Choose Any one technical object from the below and use the Algorithm of System Operator and also develop the system operator window for an Anti System
- pocket (any personal portable) computer with broadband access to the Internet and functions of a mobile videophone
- credit card
- music digital CD
- digital photo
- watch
- street lamp
- iron
- ticket for a plane
- window wiper of the car.

GEN TRIZ Methodology – Science of Innovation

1. Use a scientific problem solving approach; not just inspiration

GEN TRIZ TRIZ Innovation Roadmap



Portfolio Analysis
- Innovation Portfolio Analysis
- Selection of right products for innovation

Needs Analysis
- Identification and analysis of Main Parameters of Value (MPVs)
- Voice of the Product Analysis
- Selection of Innovation Targets
- Conversion of MPVs to physical parameters
- Trends of Engineering Systems Evolution

Problem Identification
- Benchmarking
- S-curve Analysis
- Function Analysis
- Flow Analysis
- Cause-Effect Chain Analysis
- Trimming
- Feature Transfer
- Key Problem Selection

Problem Solving
- Principles of Resolving Contradictions
- Function-Oriented Search
- Standard Inventive Solutions
- ARIZ
- Scientific Effects Database
- Clone Problems
- Trends of Engineering System Evolution

Concept Substantiation
- Super-Effect Analysis
- Adaptation Problems identification
- Failure Anticipation Analysis
- Global Knowledge Network
- IP potential evaluation
- Business impact justification

Verification / Implementation
- Smart Verification Labs
- Adaptation problems solving
- IP protection
- Risk mitigation analysis

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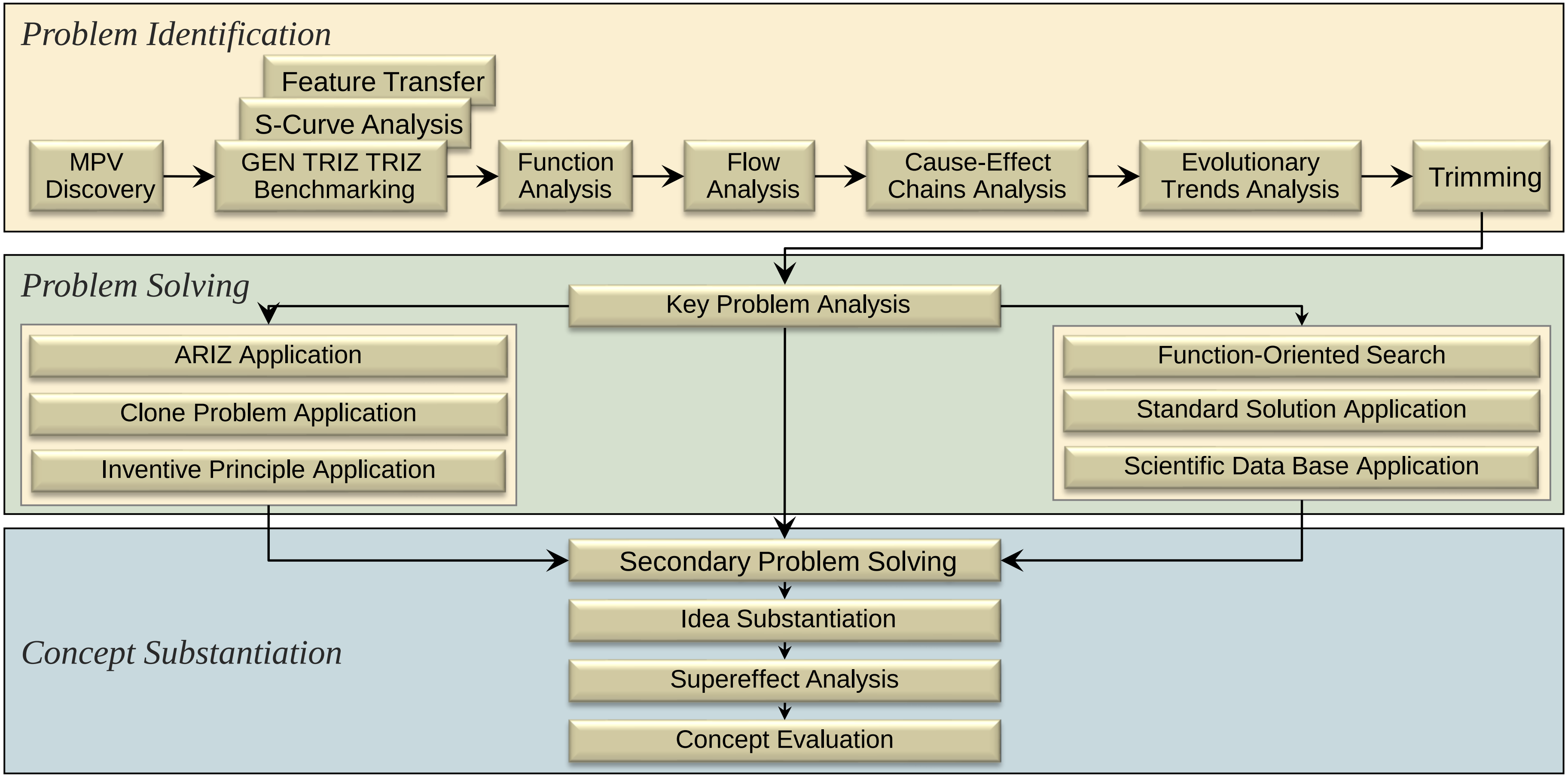
The GEN TRIZ Innovation Roadmap



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General Project Overview

Project Structure and Schedule	**Stage 1** Analysis and Problem Identification	**Stage 2** Problem Solving and Idea Generation	**Stage 3** Preliminary Substantiation	**Stage 4** Verification and Prototyping
	4 weeks	**4 weeks**	**4 weeks**	**TBD**
	Go-no-go decision	Go-no-go decision		
Goals:	• Identify key technical problems that have to be solved to achieve the project objectives	• Develop cost effective solutions for the identified key problems	• Ensure feasibility of implementing the selected developed solutions	• Verify and prototype one of the selected solutions (TBD)
Activities:	• Benchmark available technologies and identify the most suitable one • Identify key problems to be solved in order to implement the technology identified • Develop and prioritize conceptual directions to solve these problems • Develop preliminary solutions to illustrate conceptual directions	• Develop solutions within the conceptual directions • Rank the solutions and jointly and select up to 2 of them for substantiation on Stage 3 • Preliminary evaluate Freedom to Operate for the selected solutions	• Develop “reasons to believe” that proposed solutions are feasible • Estimate potential cost savings • Develop recommendations for the implementation steps at lab and industrial scale • Preliminary evaluate IP potential	• Develop and build a proof-of-principle prototype (PoP) of the selected solution • Test the PoP • Refine the product design based on the test results
Deliverables:	• Key problems to be solved to address the project objectives • Prioritized conceptual directions for solving key problems • Preliminary solutions illustrating conceptual directions	• List of solutions that solve key problems • Ranking of developed solutions • Solutions selected for Stage 3	• “Reasons to believe” that proposed solutions are feasible (publications, experts' opinion, computer simulation, calculations, etc.) • IP potential evaluation results • Recommendations for the implementation steps	• Model prototype of the final product

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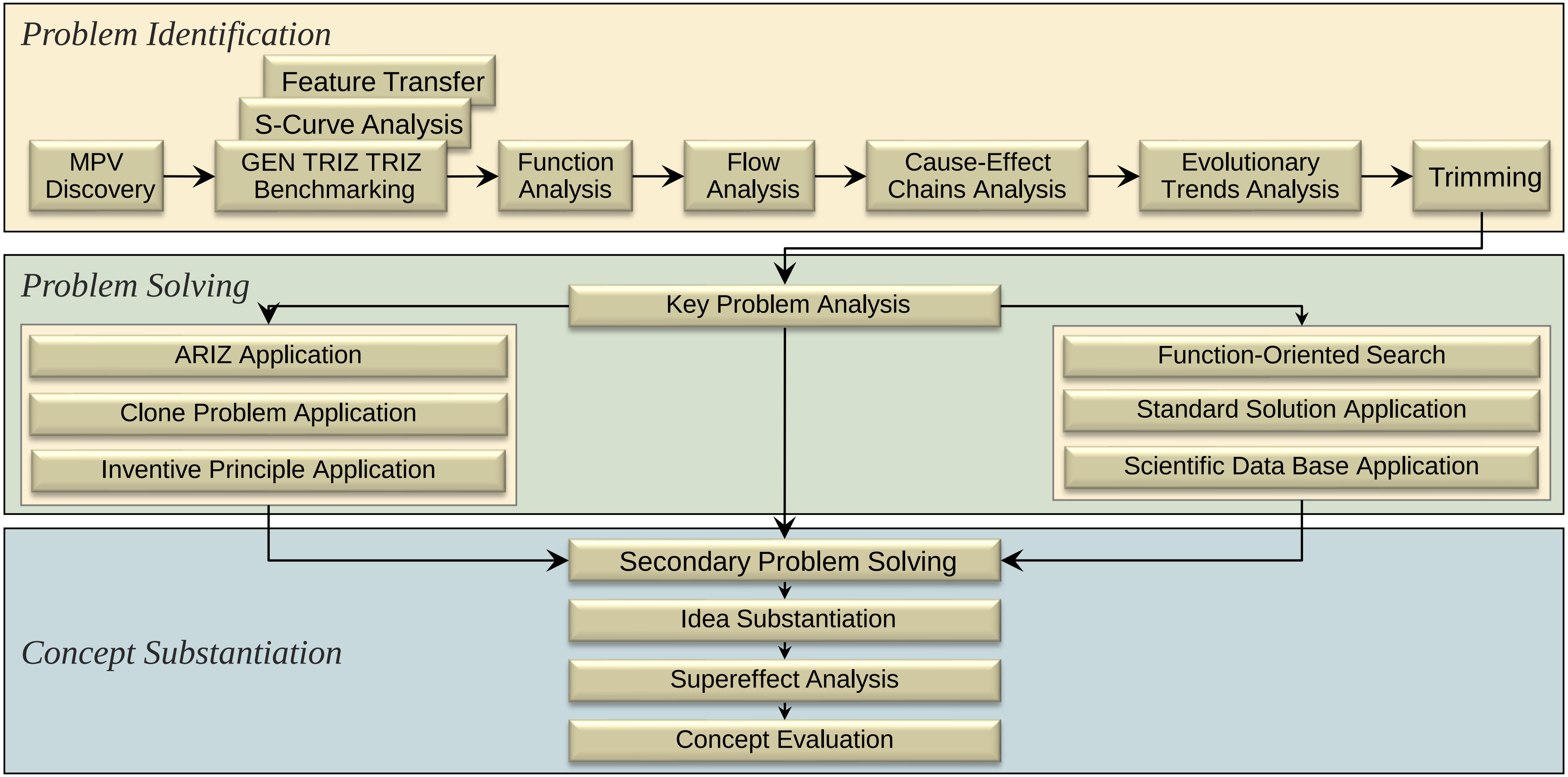
The GEN TRIZ Innovation Roadmap



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What is Innovation?

Innovation: Commercially available significant improvement along a Main Parameter of Value (MPV)

MPV: Key attribute/outcome of a product/service that is important to the purchase decision process

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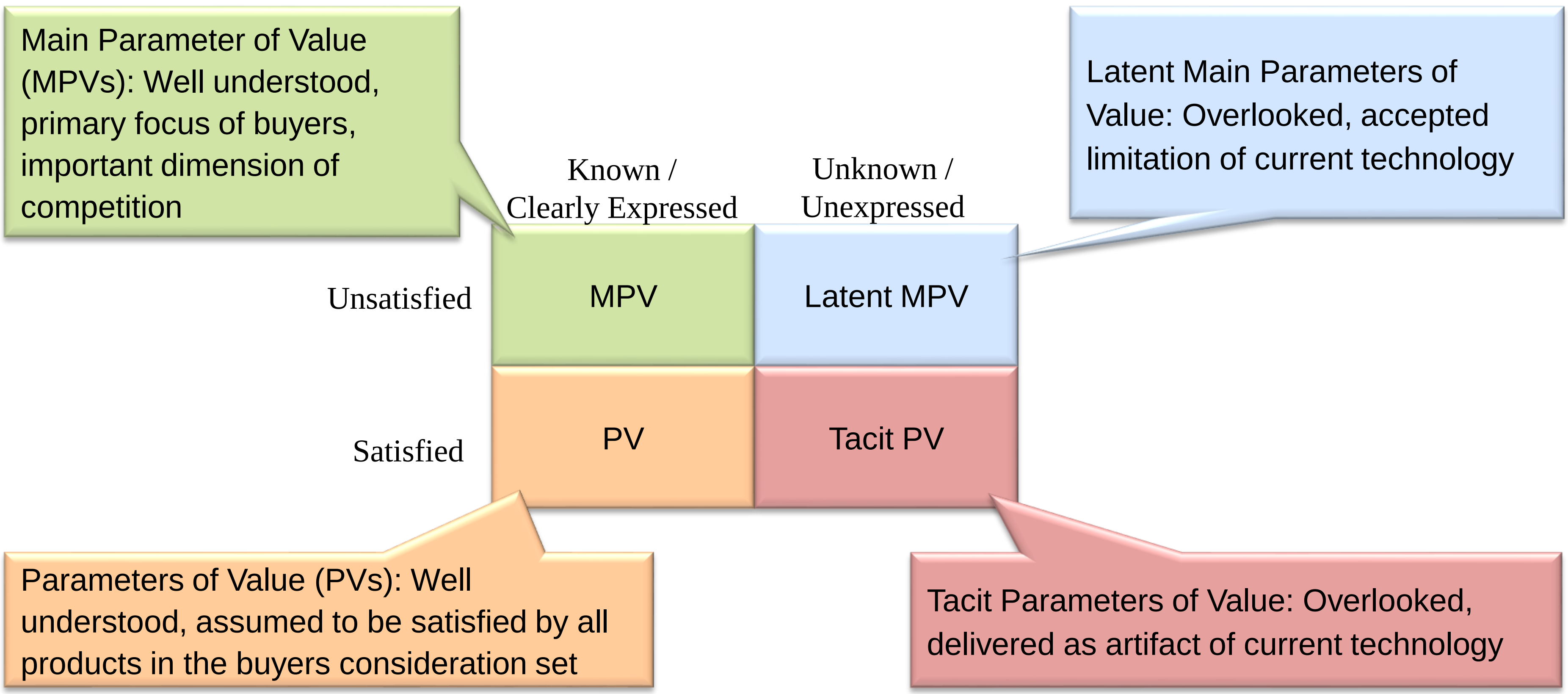
MPV Analysis



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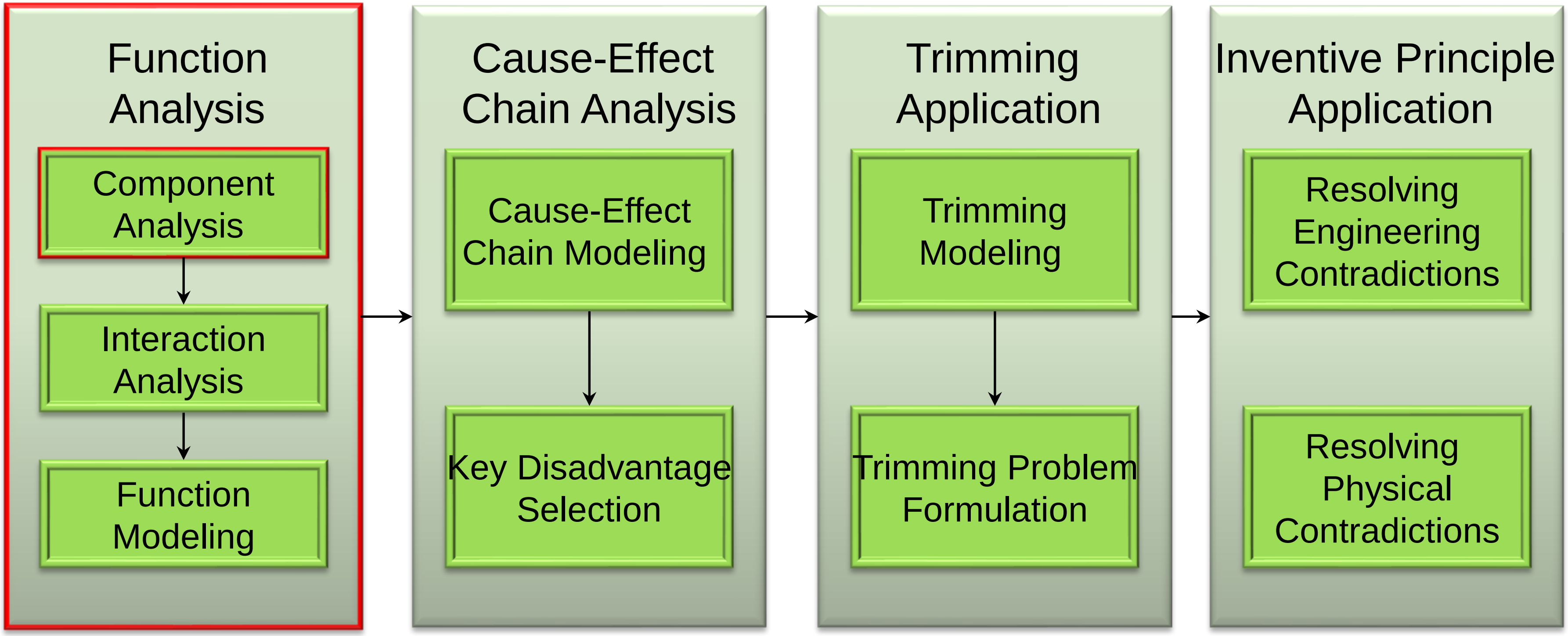
The GEN TRIZ Product Innovation Roadmap (For Level 1)



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FUNCTION ANALYSIS

Function Analysis: Definition

Function Analysis is an analytical tool that identifies functions, their characteristics, and the cost of the System and the Supersystem components.

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Stages of Function Analysis

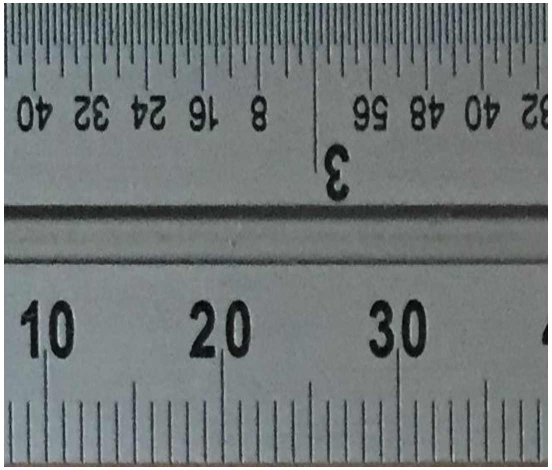
- Component Analysis
- Interaction analysis
- Function Identification
- Function Performance Analysis
- Function Ranking analysis

COMPONENT ANALYSIS

Component analysis

- Definition of Component analysis: It is a procedure in problem definition stage that is used to identify components of an engineering system and the Super System
- Definition of component: A component is a part of an Engineering system , where an Engineering system is defined as a system is assigned to perform a function
  - The component can be a substance (object with rest mass)
  - The component can be a field (an object without rest mass that transfers interaction between substances)
  - Or a combination of Substance and Feild
- Definition of System: Group of elements that are interconnected and interact to form an integrated whole possessing properties not inherent to the elements taken separately and assigned to perform a function
  - Corollary: Parameters cannot be identified as Components
- Super system: System that contains the analyzed engineering system as a component
- Corollary: Before starting to conduct component analysis it is important to attempt to understand the overall function of the system

Problem



- The following was the process for the manufacture of Chrome plated rulers. The rulers we made of high carbon steel and etched to have the graduations.
- After the graduations are etched the rulers were chrome plated as that gives the rulers a rich matte look and also wear resistant. In order to make the graduations visible Paint was applied over the entire surface. That way the paint would get into the graduations and also would remain on the surface.
- The rulers were then placed in an oven and baked at 100 degree centigrade for the curing of the paint, post which the rules were cooled and held under running water and workers would then use a charcoal piece and under running water rub the blank.
- The paint would remain in the graduation that was etched and would slowly come out from the other areas due to the friction being applied, However many time paint would also come out from the graduations and the process would have to be repeated. This was time consuming also it was possible that the paint would come out later when the customer was using the same this lead to complaints,
- What to do to resolve the problem at hand

Component Analysis: Guidelines for Selecting Hierarchical Level

- Select the level based on project goals and constraints
  - Low hierarchical level increases the analysis effort
  - High hierarchical level may provide insufficient information
- Select Components at the same hierarchical level
- Consider similar Components as one Component
  - Six nuts of same type can be treated as Component “nuts”
- If a Component requires more thorough analysis, redo Component Analysis at lower hierarchical level

Head

Web

Foot

Rails Sleepers

Railway lines Stations

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Function Analysis. Component Model

System Component	Supersystem Component
Ink	Ruler
Water	Light
Charcoal	Human
Oven(incuding heat)	

Interaction Analysis

- Interaction analysis identifies interaction between components be it system components or super system
- Interaction is defines as components that physically touch each other
- To conduct an interaction analysis just list all the components of the system and Super system in a vertical and Horizontal row and evaluate for touch

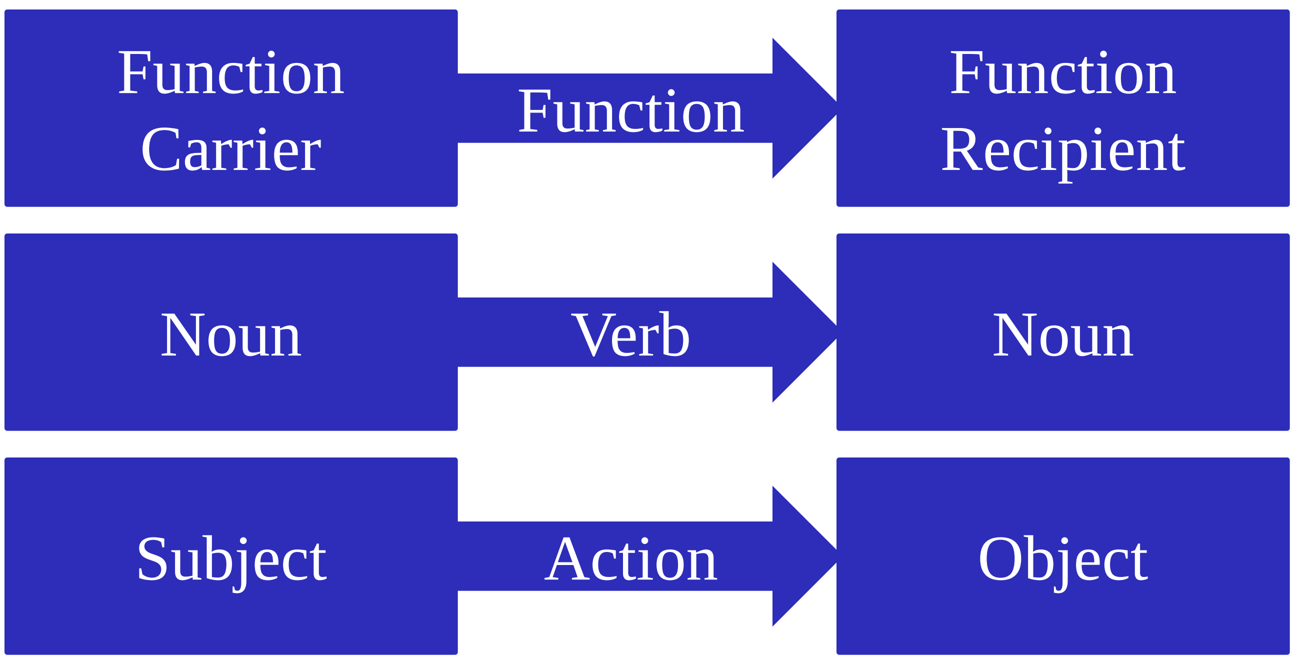
	Component1	Component2	Component3	Component4	Component5
Component1		+	-	+	+
Component2	+		-	+	-
Component3	-	-		-	+
Component4	+	+	-		+
Component5	+	-	+	+	

Function Analysis. Interaction Matrix

	Ink	Water	Charcoal	Oven(incuding heat)	Ruler	Light	Human
Ink		+	+	+	+	+	+
Water	+		+	-	+	+	+
Charcoal	+	+		-	+	+	+
Oven(incuding heat)	+	-	-		+	+	+
Ruler	+	+	+	+		+	+
Light	+	+	+	+	+		+
Human	+	+	+	+	+	+	

Function Identification

- Definition of a Function: An action performed by one component to change or maintain a parameter of Another component



Rules for existence of function

1. Both the Function Carrier and the Recipient have to be components

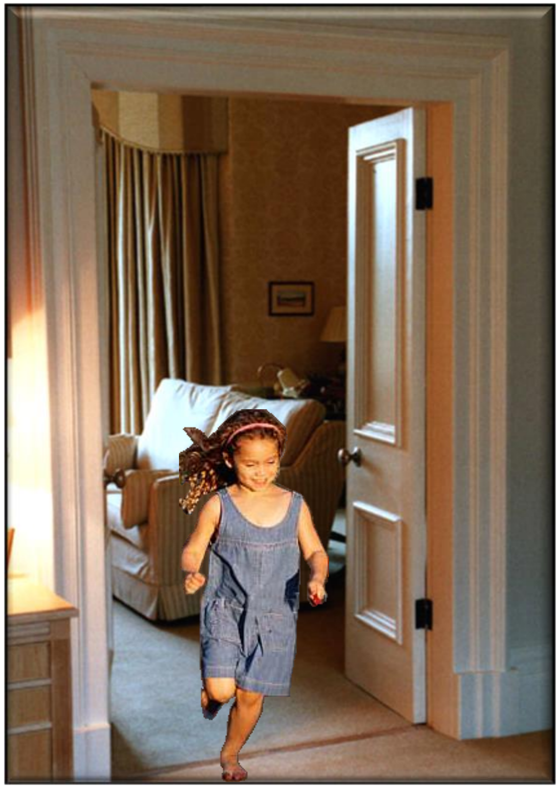
2. Function carrier has to interact with the object of the function

3. Parameters of the object of the function either change or are maintained as a result of the function

Function Modeling
Example: Function of an Open Door

- ~~To allow the person to pass~~
- ~~Not to stop the person~~
- ~~To provide an open passage~~

- No Functions between the open door and the running person because there is no interaction between them



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Function Modeling
Example: Helmet

- ~~To protect the head~~
- ~~To save the soldier~~
- ~~To provide safety~~
- ~~Not to pass a bullet~~

- To deflect a bullet
- To stop a bullet

Helmet

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Function Modeling
Example: Toothbrush

- ~~To clean teeth~~
- ~~To brighten teeth~~
- ~~To keep teeth clean~~
- ~~To prevent cavities~~
- ~~To make teeth healthy~~

- To remove plaque (from teeth)
- To remove food (from teeth)

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Function Modeling:
Guidelines for naming a Function

- No negative formulations
- No declarative formulations
- Be as specific as possible
- When can’t think of a verb, use “X changes Y parameter of Z”
- Document only consequential functions (e.g., “air cools soup”, not “soup heats air”)

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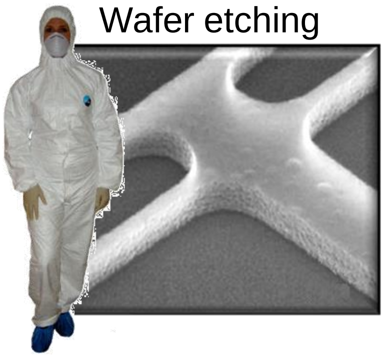
Function Language as an Interdisciplinary Esperanto

Wafer etching

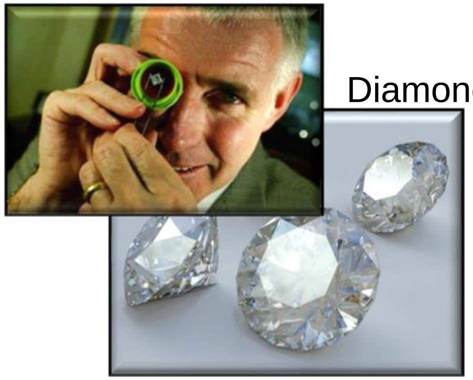


Fossil restoration

Function: To remove particles

Teeth cleaning

Diamond facing



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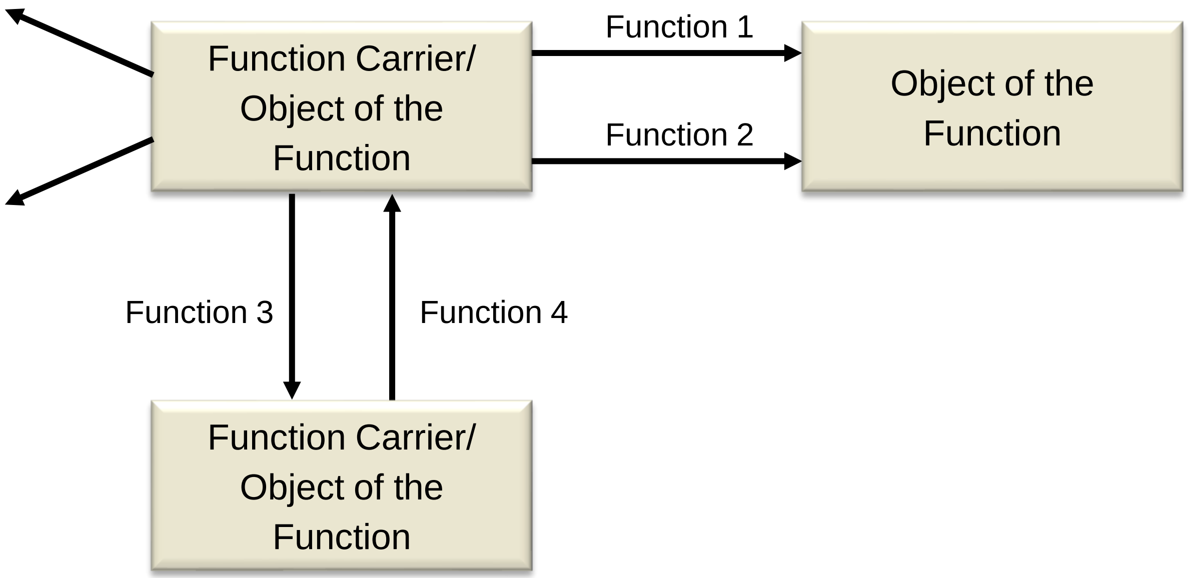
Function Modeling:
Typical Function Model



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Function Modeling:
Main Function

The function for which the System was designed

Main Function of the car is to move passengers and cargo

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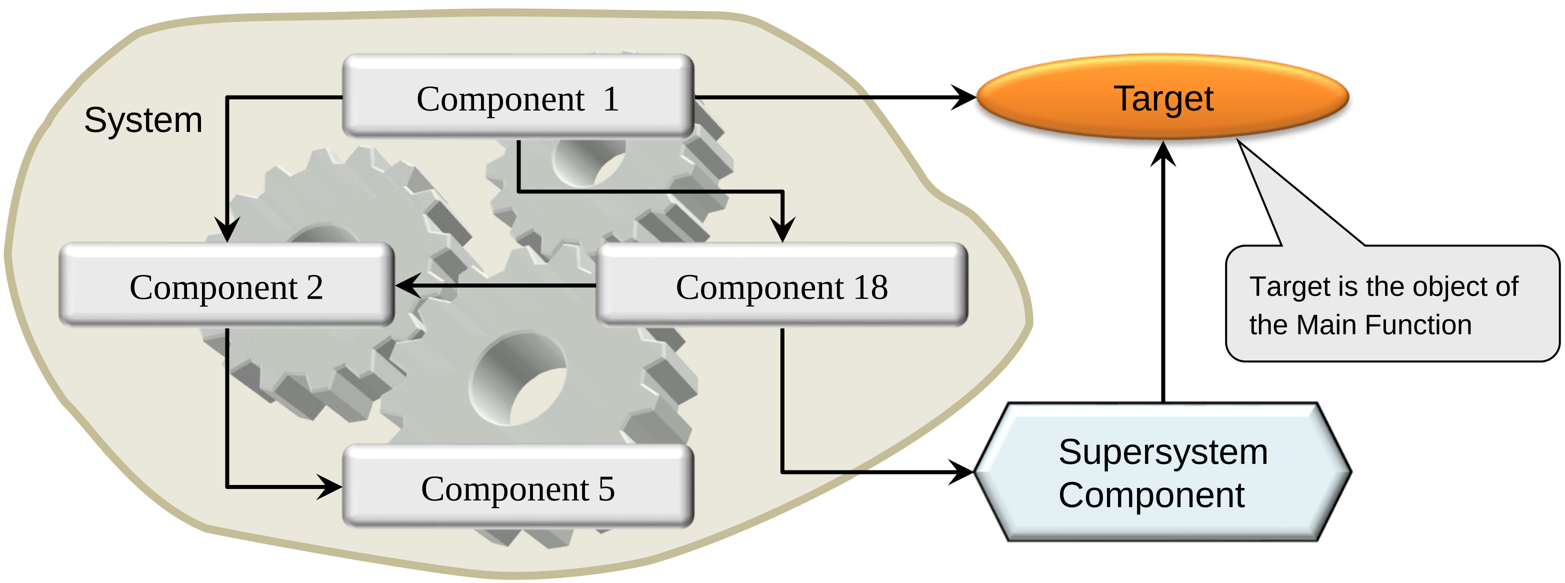
Function Modeling: Target

Target is the Object of the Main Function of an Engineering System



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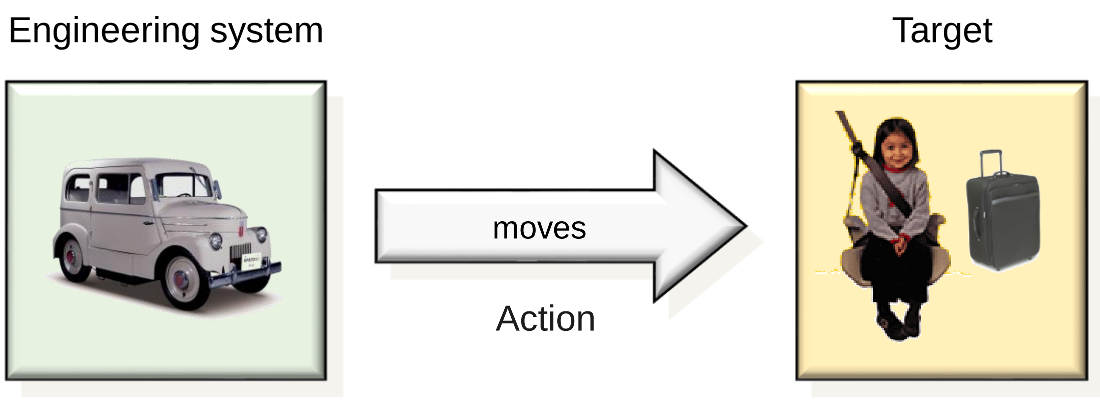
Function Modeling:
Target

Identifying the Target: Example – A Car

- The Main Function of a car is to move passengers and cargo
- The Targets of the car are passengers and cargo and both belong to the Supersystem
- Parameter change in the Targets is their physical location



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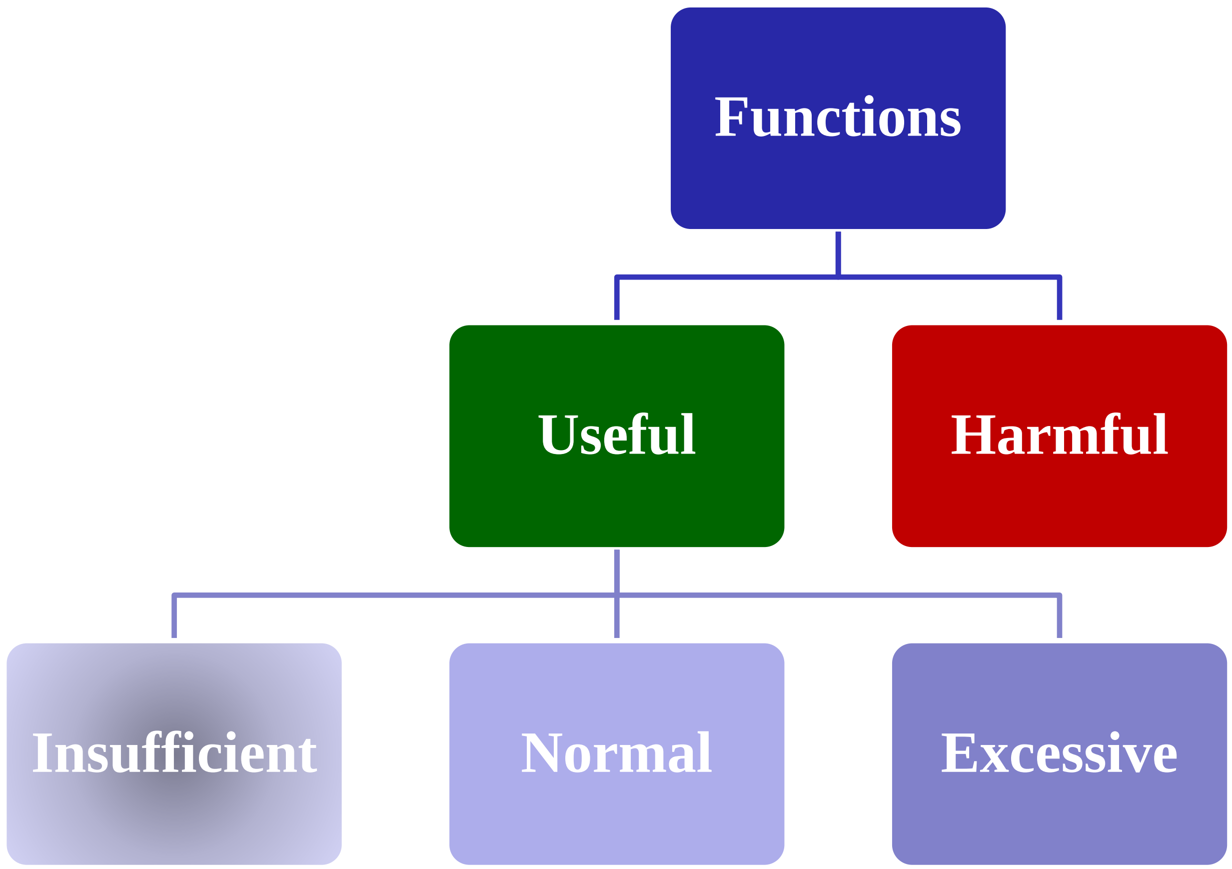
Function Performance analysis



Function Modeling: Function Categories

- Useful Function
  - Changes the Parameters of the Object of the Function in a desired direction
- Harmful Function
  - Worsens the Parameters of the Object of the Function
  - Harmful function is a Function Disadvantage
- Example: Function “to destroy a car”

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Function Modeling
Example: Toothbrush

- Useful Functions
  - Bristles Distribute Toothpaste
  - Bristles remove Food
- Harmful Function
  - Bristles damage the Gums

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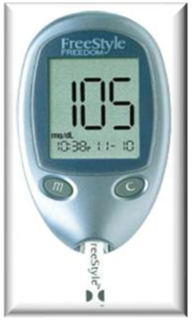
Function Modeling:
Performance of Useful Functions

- Level of performance is a difference between the “required value” and the “actual value” of a selected criterion of function evaluation. The typical criterion is a function parameter
- Excessive level: actual value > required value
- Insufficient level: actual value < required value
- Excessive and Insufficient levels are Function Disadvantages

Insufficient | Normal | Excessive

Performance

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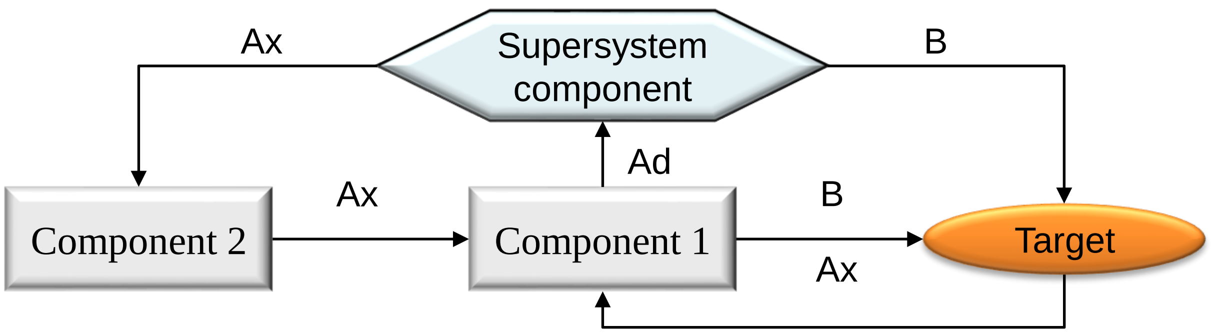
Function Analysis. Function Table

Function carrier	Action	Object of the function	Category	Rank	Performance	Comments
Ink	pollutes	Water	Harmful			
	reflects	Light	Useful	Additional	Insufficient	
Water	moves	Ink	Useful	Auxiliary	Insufficient	
Charcoal	scrathes	Ruler	Harmful			
	moves	Ink	Useful	Auxiliary	Excessive	
	pollutes	Water	Harmful			
Oven(incuding heat)	heats	Ruler	Useful	Basic	Excessive	
	cures	Ink	Useful	Auxiliary	Excessive	
Ruler	holds	Ink	Useful	Auxiliary	Insufficient	
	wears	Charcoal	Harmful			
	reflects	Light	Useful	Additional	Insufficient	reflection of light from the graduations and the chrome
Light	informs	Human	Useful	Additional	Insufficient	
Human	moves	Ruler	Useful	Basic	Normal	
	moves	Ink	Useful	Auxiliary	Excessive	
	moves	Charcoal	Useful	Auxiliary	Excessive	
	operates	Oven(incuding heat)	Useful	Auxiliary	Normal	

Function Modeling:
Ranking Useful Functions

- Functions closer to the Target are more important and therefore ranked higher than those away from it
- A Function directed at the Target is a Basic Function and is assigned the highest rank (3 points)
- A Function directed at a Supersystem Component other than the Target is an Additional Function (2 points)
- A Function directed at a Component of the Engineering System is an Auxiliary Function (1 point)



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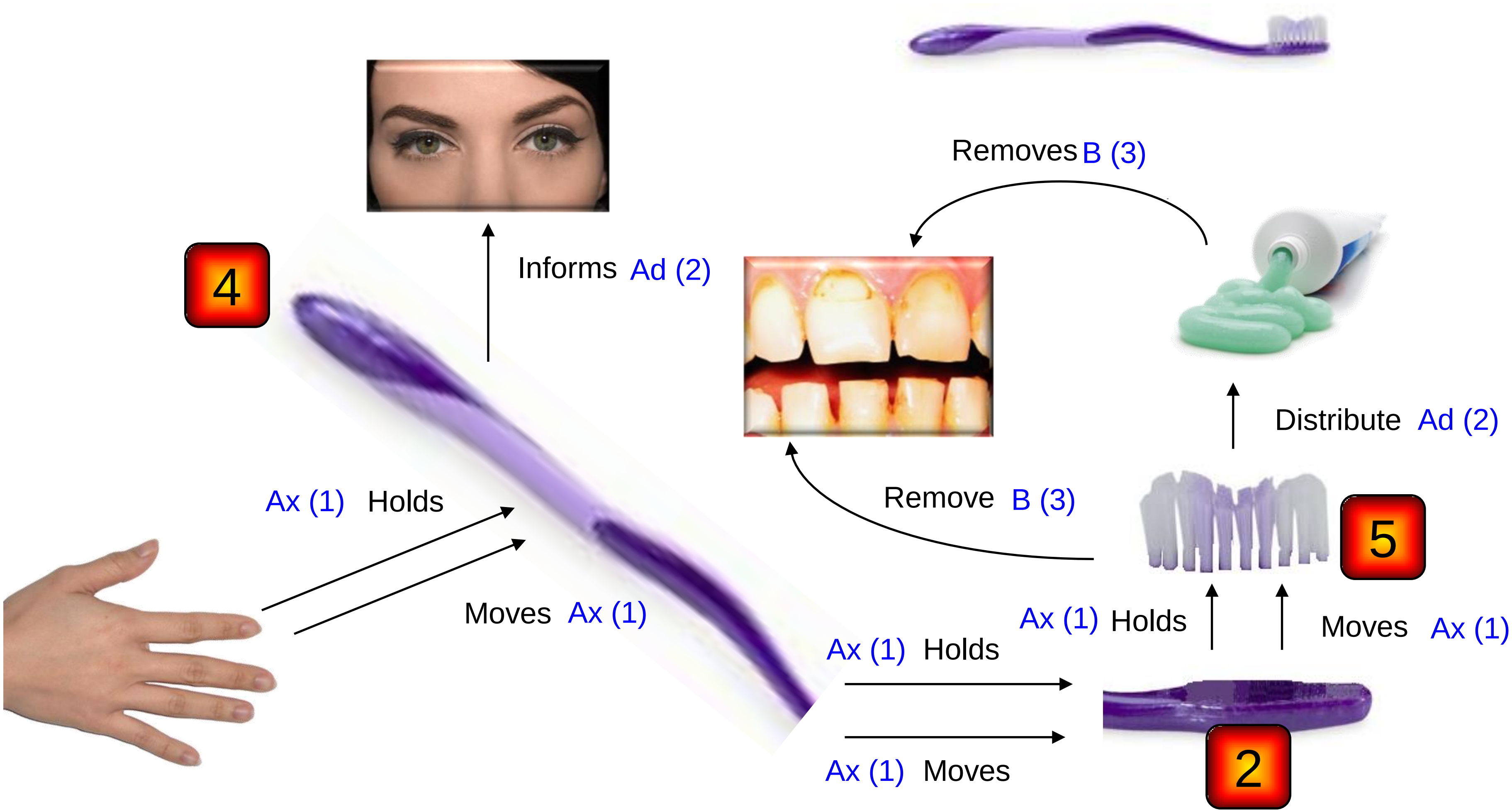
Function Ranking



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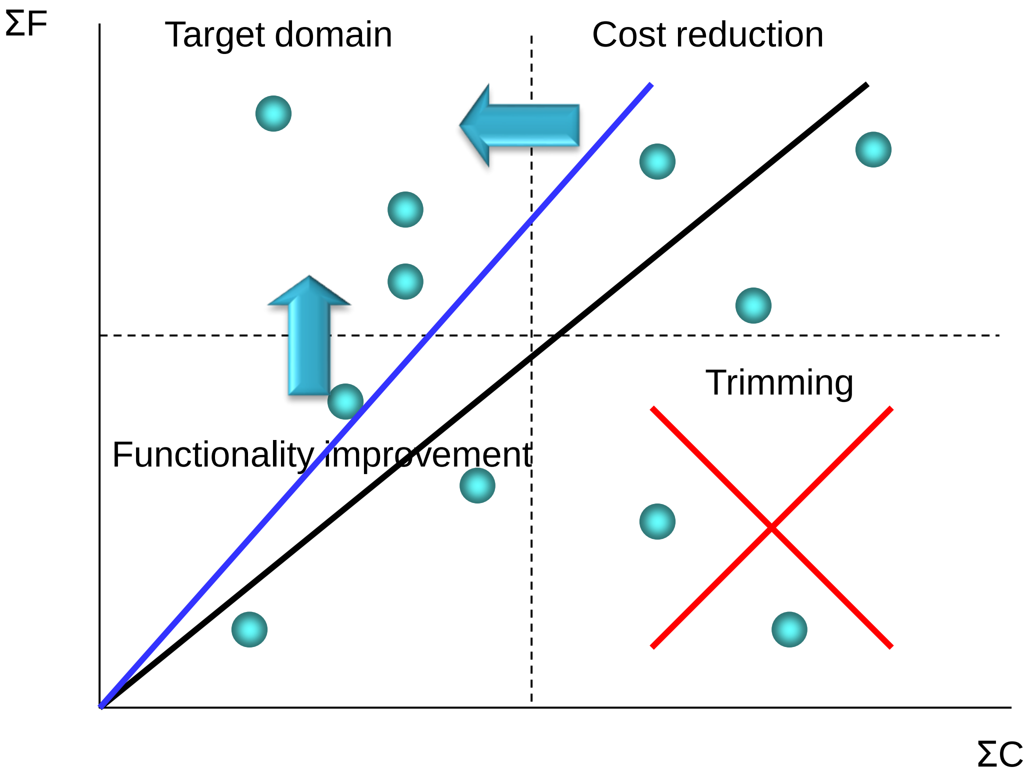
Function – Cost Diagram



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Function Analysis. List Of Disadvantages. Harmful Functions

Function	Comments
Ruler wears Charcoal (harmful)	
Ink pollutes Water (harmful)	
Charcoal scrathes Ruler (harmful)	
Charcoal pollutes Water (harmful)	

Function Analysis. List Of Disadvantages. Inadequate Useful Functions

Function	Comments
Ruler holds Ink insufficiently	
Ruler reflects Light insufficiently	reflection of light from the graduations and the chrome
Ink reflects Light insufficiently	
Water moves Ink insufficiently	
Charcoal moves Ink excessively	
Oven(incuding heat) heats Ruler excessively	
Light informs Human insufficiently	
Human moves Ink excessively	
Human moves Charcoal excessively	
Oven(incuding heat) cures Ink excessively	

Function Modeling

- How to Create a Function Model?
  - Indicate a Component
  - Identify and indicate all the Functions of the indicated Component, using the Interactive Matrix
  - Determine and indicate Function Ranks
  - Determine and indicate Performance level of Function
  - Repeat steps 1–4 for other Components
- Identifying Functions
  - Refer to the Interaction Matrix. All cells containing a '+' sign in the Interaction Matrix show an interaction between the Components in the row and column of those cells.
    - + cell can contain one Function, many Functions, or no Functions
    - - cell does not contain any Functions

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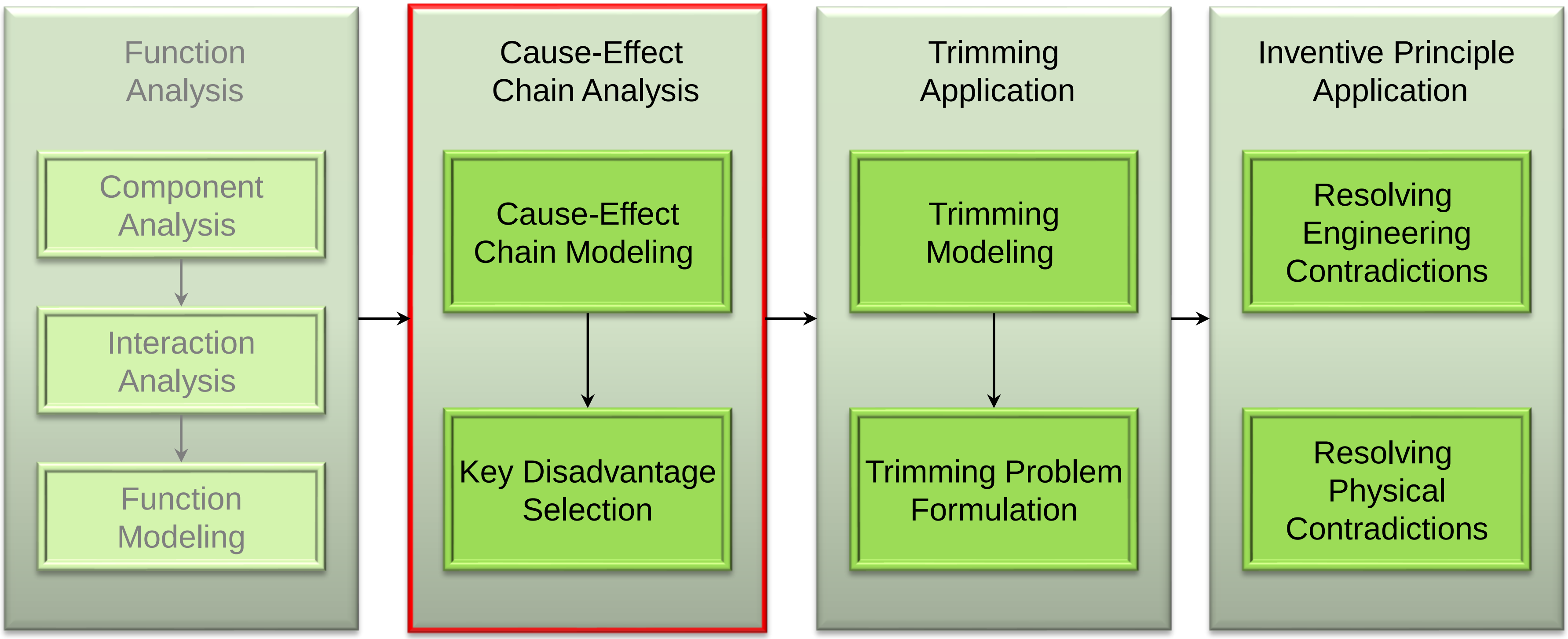
Function Analysis

- The main goals of function analysis is to have a functional representation of the Engineering system
- Identify components that carry functional disadvantages with them
- Rank functions so that we have a model to understand functional importance of components
- Provide a thorough understanding of the functionalities of the system
- Provide an input to the cause and effect chain analysis of the system
- Provide an input to Trimming

The GEN TRIZ Product Innovation Roadmap



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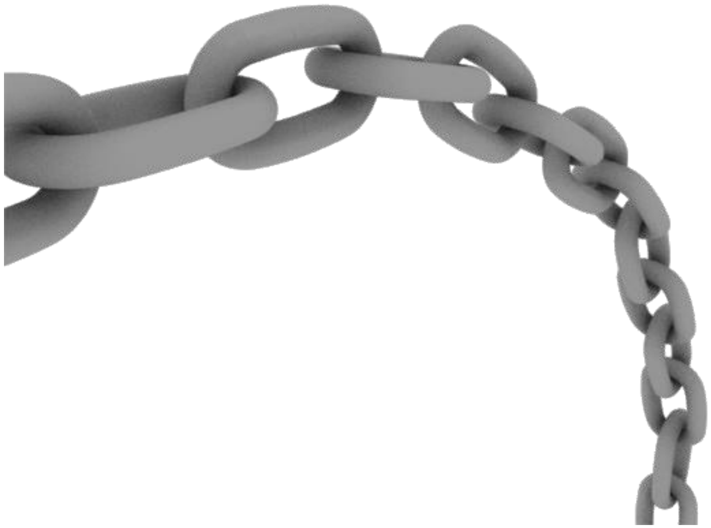
Cause-Effect Chain Analysis: Definition

Cause-Effect Chain Analysis is an analytical tool that identifies the Key Disadvantages of the analyzed Engineering System. This is accomplished by building Cause-Effect Chains of disadvantages that link the Initial Disadvantage to its fundamental causes.



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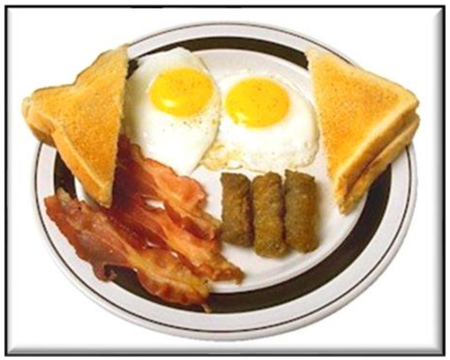
Cause-Effect Chain Analysis Example



Wrong diet → Causes → Excessive salts in the blood → Causes → High blood pressure → Causes → Headache

Key Disadvantage

Initial Disadvantage

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Cause-Effect Chain Analysis at a Glance

- Disadvantages are identified during Function Analysis and Flow Analysis. Usually, a large number of disadvantages is identified
- Many of these disadvantages are caused by only a few underlying Key Disadvantages
- When Key Disadvantages are removed, all preceding disadvantages are eliminated
- The ultimate goal of Cause-Effect Chain Analysis is to identify Key Disadvantages

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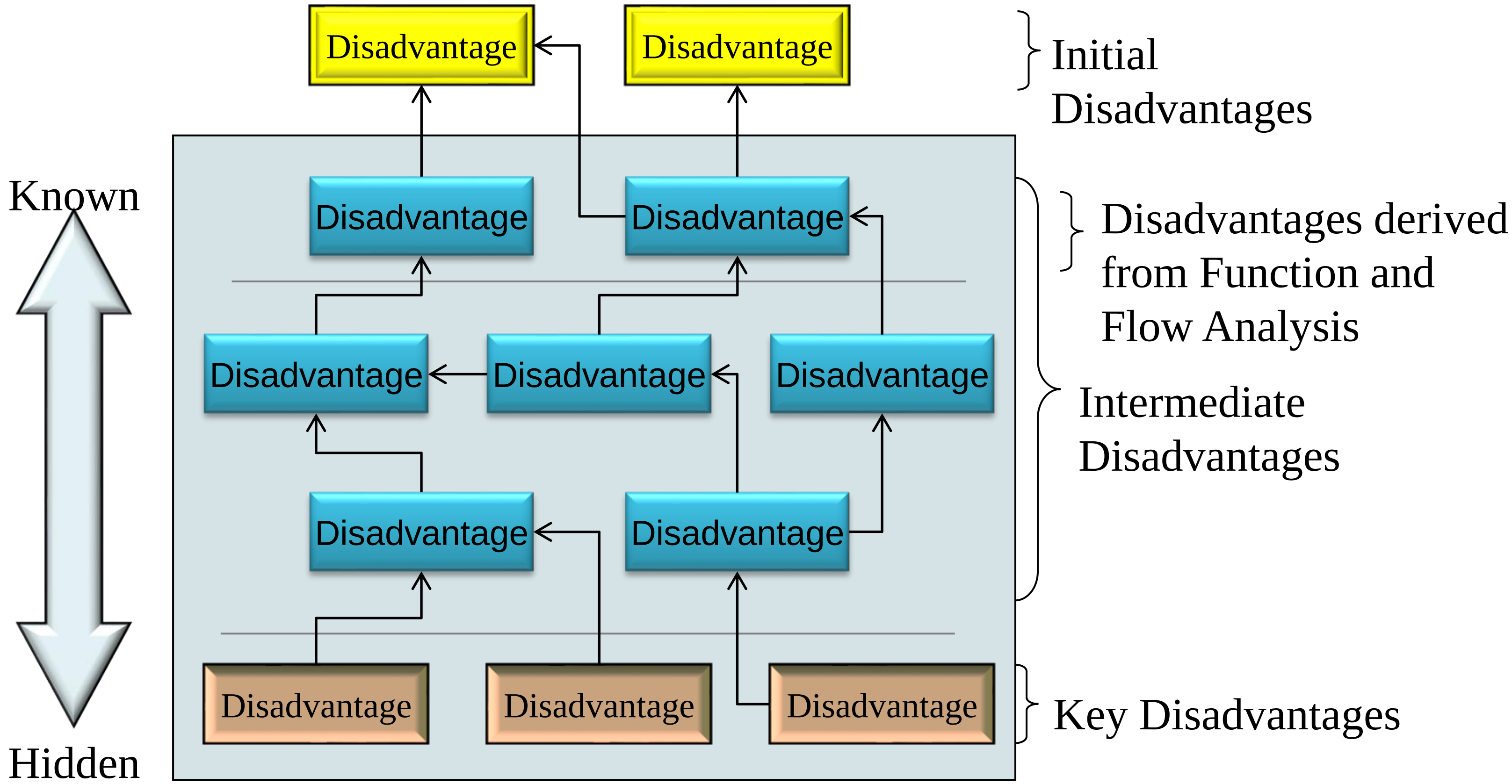
Cause-Effect Chain Analysis
Typical Cause-Effect Chain



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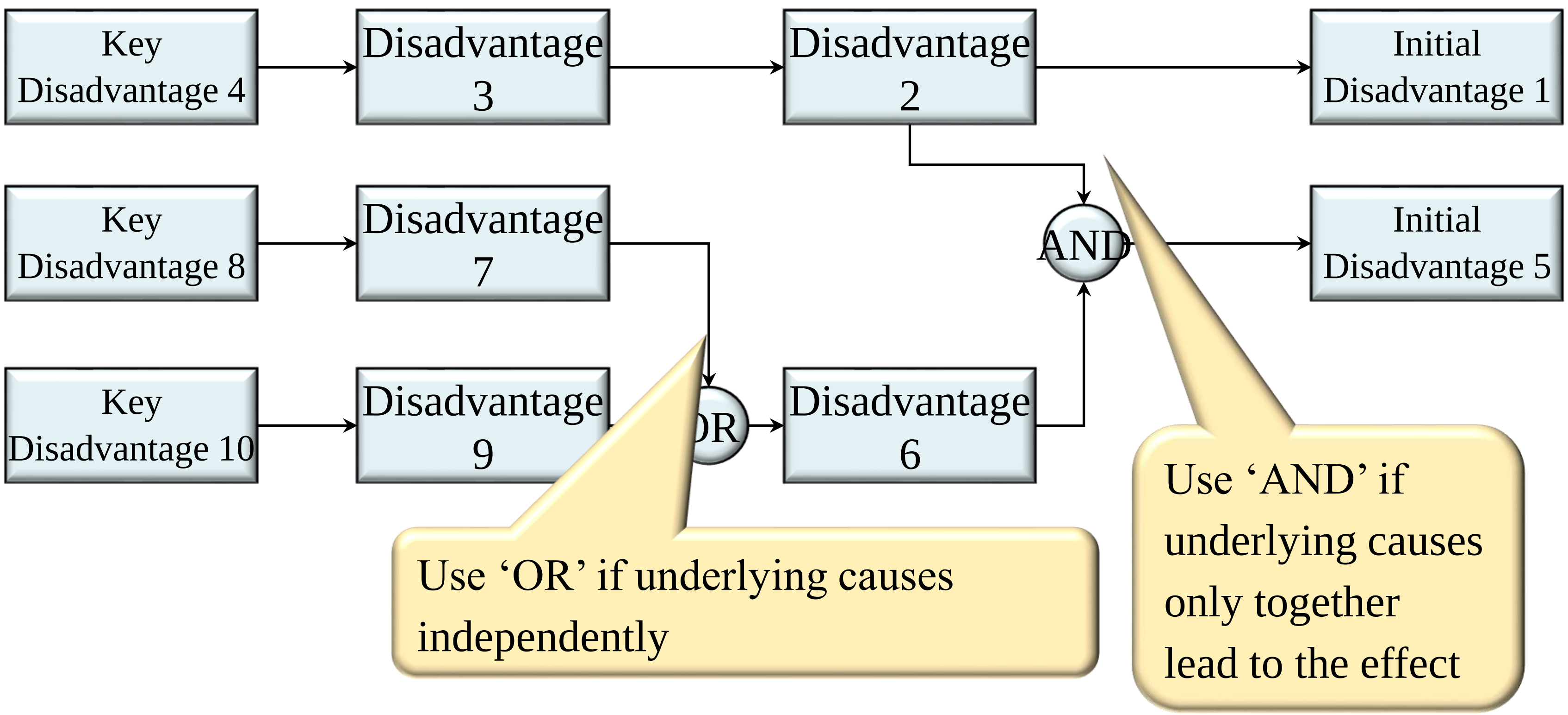
Cause-Effect Chain Analysis Outcome

- Cause-Effect Chains Analysis Model
- Set of Key Disadvantages lead to the effect



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Cause-Effect Chain Analysis
Algorithm for Creating a Cause-Effect Chain Model

1. Write the first Initial Disadvantage
2. Identify the cause(-s) of the Disadvantage:
   - Check the list of disadvantages from Function Analysis
   - Ask experts
   - Use a qualitative scientific equation:
     1. Identify parameters affecting the disadvantage: $D = f(P_1, P_2, P_3)$
     2. Decide how to change these parameters to eliminate the disadvantage: $D = f(\uparrow P_1, \downarrow P_2, \uparrow P_3)$
     3. Formulate causes of the disadvantage: insufficient P_1, excessive P_2, insufficient P_3
3. Repeat step 2 until you reach a cause that has physical, chemical, biological, or geometrical fact as its underlying cause
4. After completing the Cause-Effect Chain Model select Key Disadvantages

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Cause-Effect Chains Analysis
Example: Coffee Bag

- The coffee bag was invented to replace an instant coffee, keeping convenience of use. But experimental samples were very ineffective due to slow coffee extraction.
- To overcome the problem of slow coffee extraction, more coffee is filled in the bag, resulting in high cost of the coffee bag
- The project goal is to reduce the cost of the coffee bag

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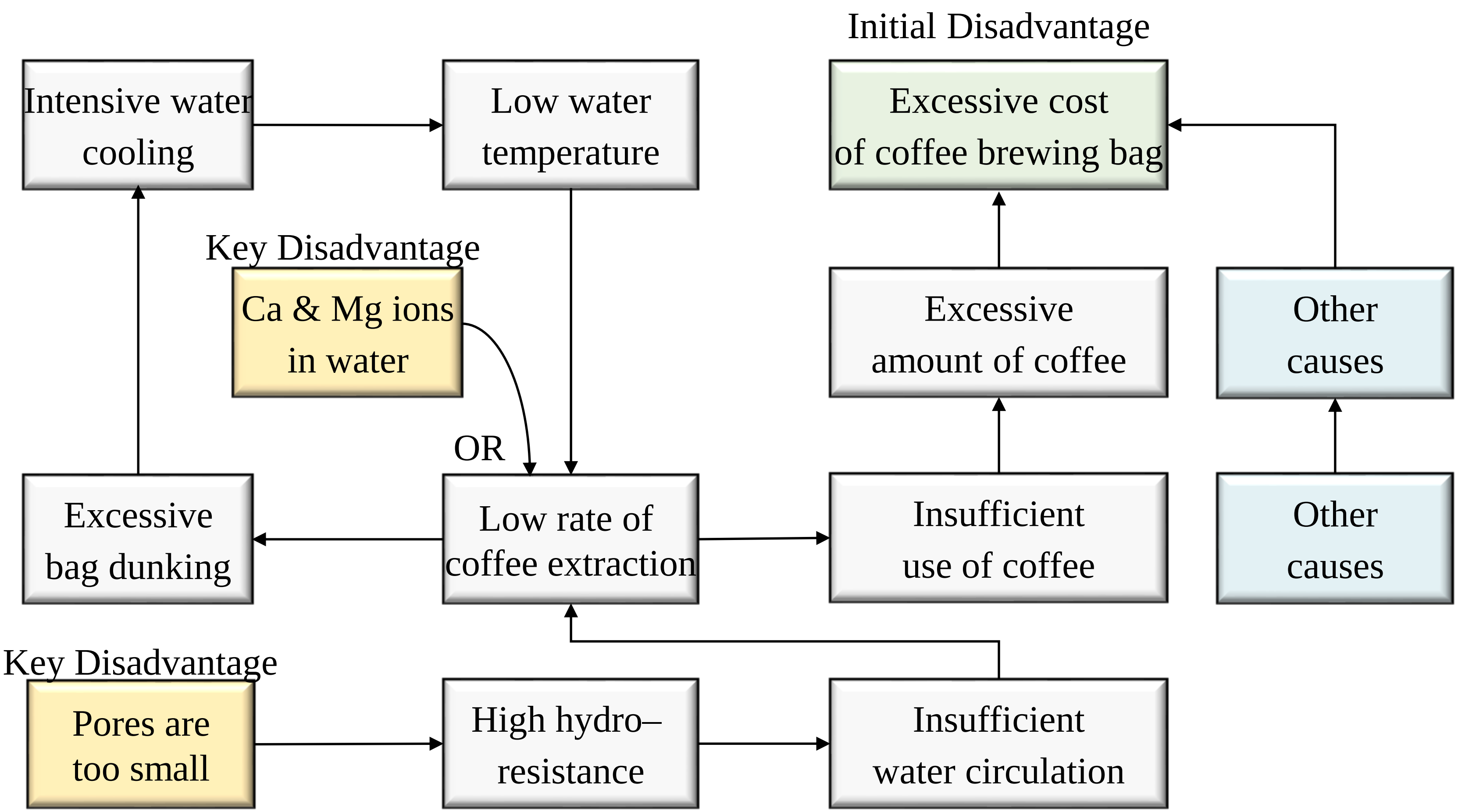
Cause-Effect Chains Analysis
Cause-Effect Chain Model of Coffee Bag



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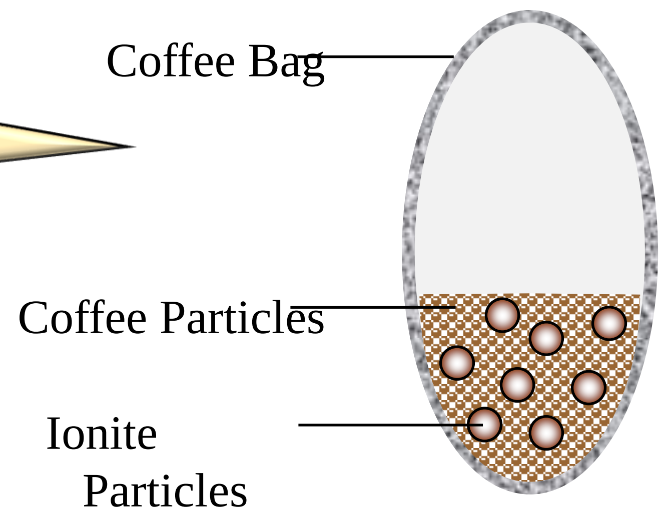
Cause-Effect Chains Analysis
Example: Coffee Bag

- Key Problems:
  - How to reduce amount of Ca and Mg ions in the water?
  - How to increase pore diameter while preventing sediment formation?
- Solution
  - The amount of Ca and Mg ions from the water is reduced by adding ionite particles in the coffee bag

Ionite particles are inexpensive and do not affect the flavour or chemical composition of the extracted coffee but are very effective in extraction the Ca and Mg ions from the water



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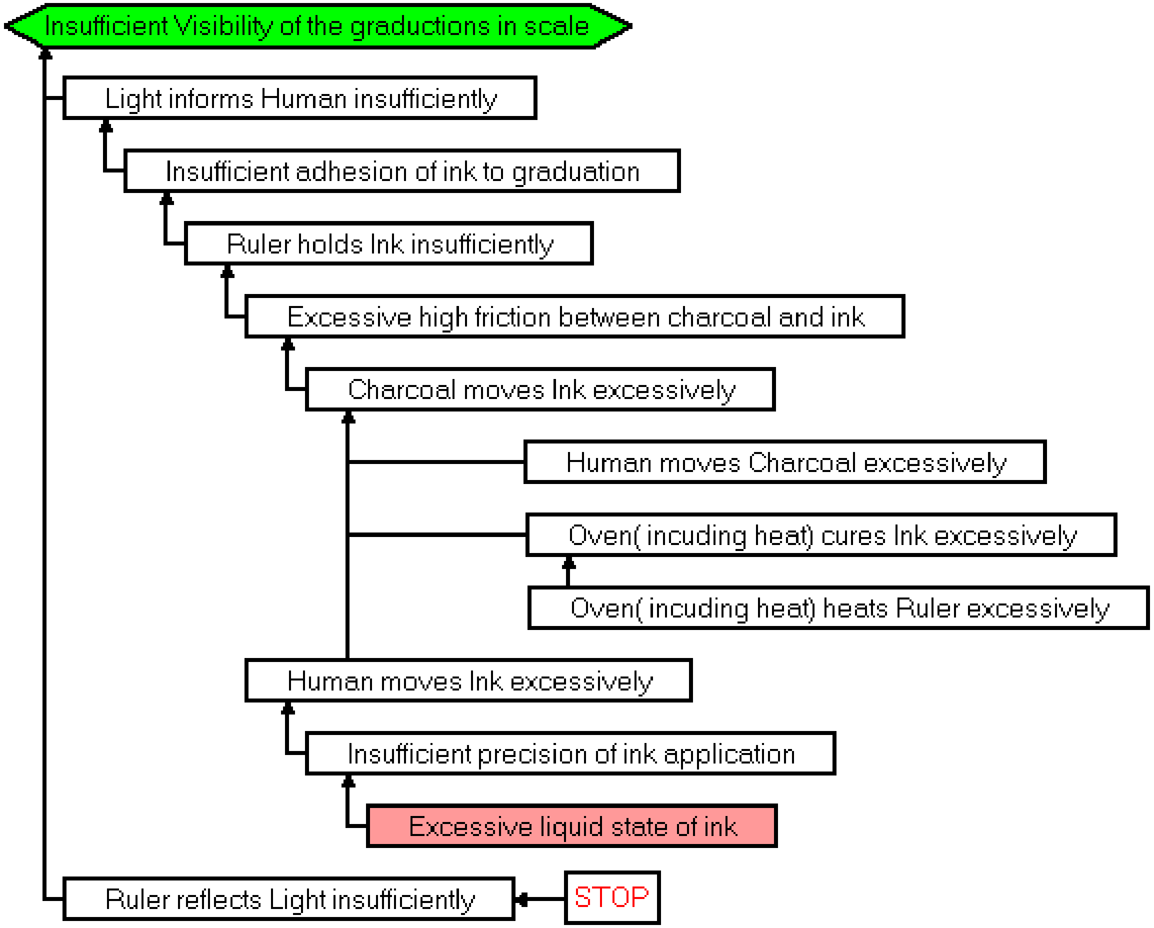
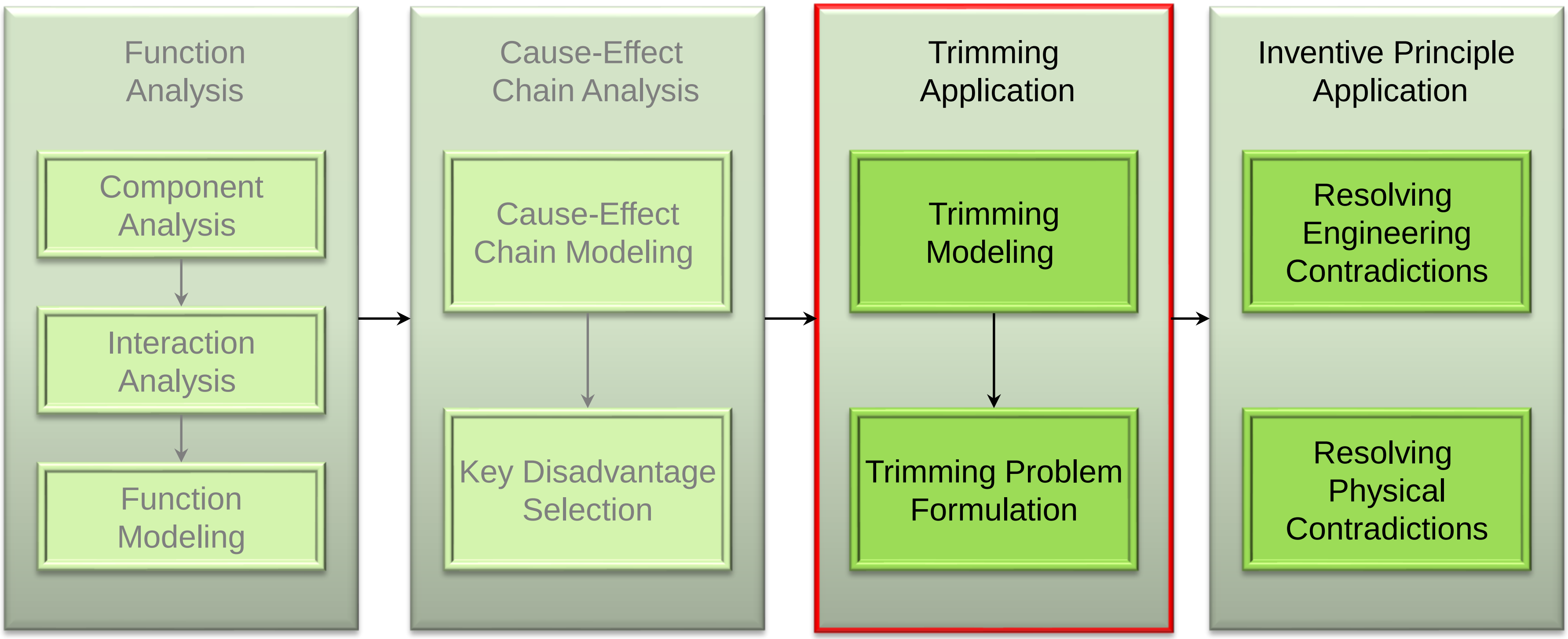
CECA. Initial Disadvantage(s)



The GEN TRIZ Product Innovation Roadmap



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Trimming: Definition

Trimming is an analytical tool for removing (trimming) certain Components and redistributing their useful functions among the remaining System or Supersystem Components.

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Trimming
Example: Motorcycle

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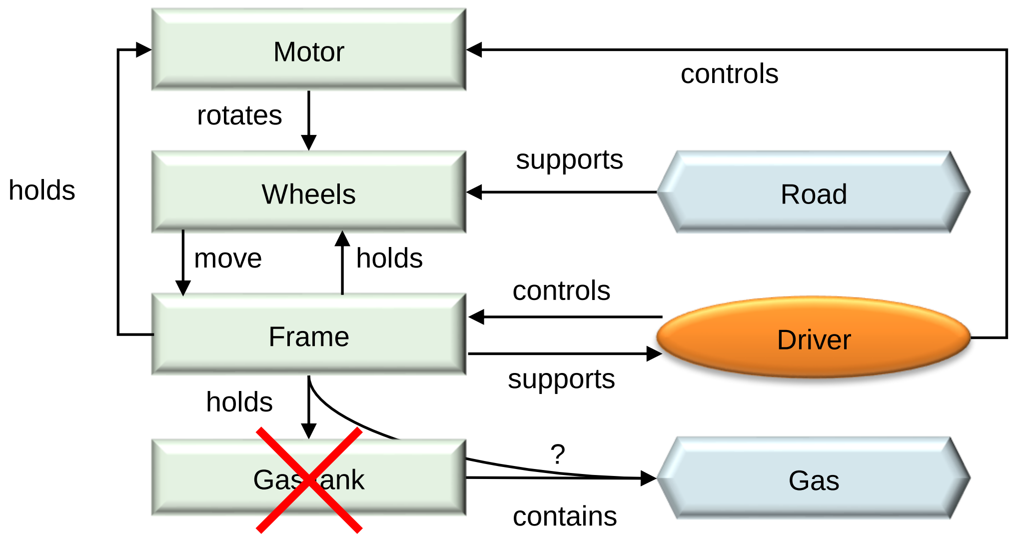
Trimming



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Trimming

The gas tank has been trimmed - function transferred to the frame

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Trimming: Guidelines

- Select components based on project's goals and constraints
- Trim the Components with Key Disadvantages in order to maximize the improvement of the Engineering System
- Perform Trimming according to the 3 rules mentioned in the next slides
- Do not trim if no acceptable alternatives are available for redistribution of the function
- Perform radical instead of incremental Trimming if project’s goals and constraints allow
- Trimming can be less or more conservative depending on the number and the relative importance of the trimmed Components

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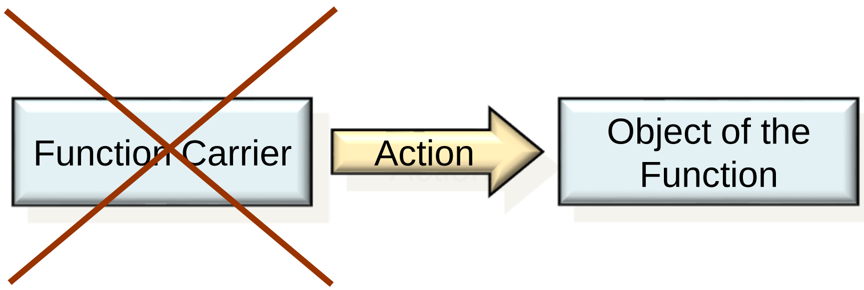
Trimming: Rules of Trimming

Rule A: Function Carrier can be trimmed if we remove the Object of its useful Function



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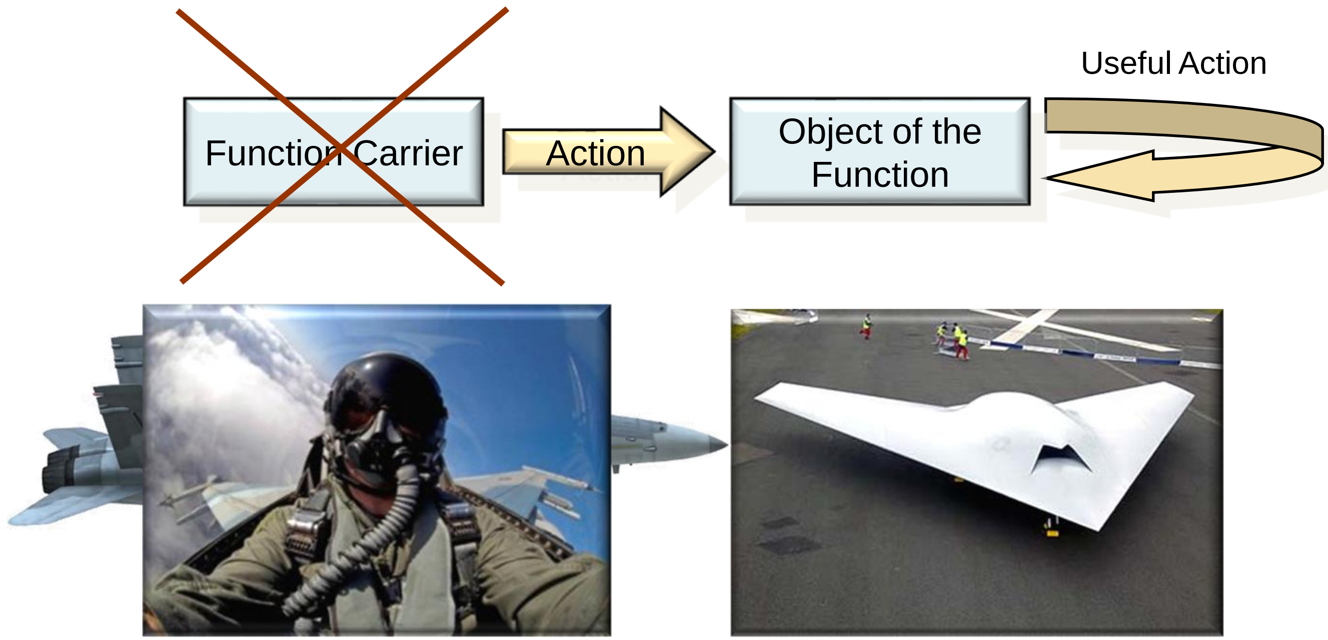
Trimming: Rules of Trimming

Rule B: Function Carrier can be trimmed if the Object of Function performs the Useful Function itself



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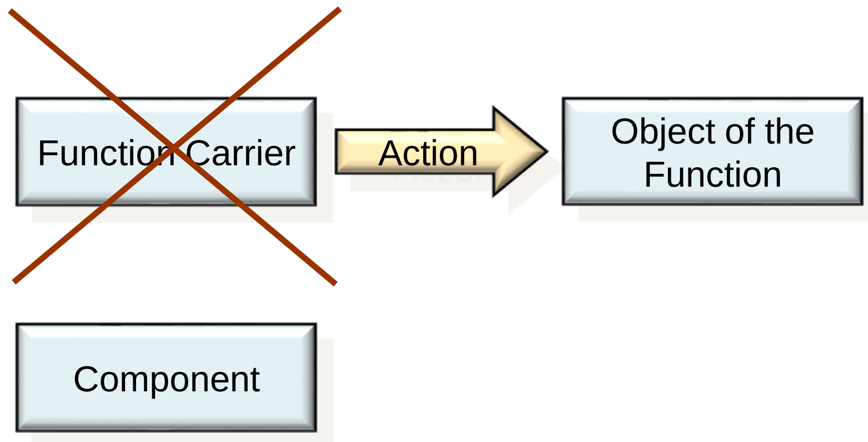
Trimming: Rules of Trimming

Rule C: Function Carrier can be trimmed if another Component performs its useful function



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Trimming: Summary of Trimming Rules

- Rule A: Function Carrier can be trimmed if we remove the Object of its useful Function
- Rule B: Function Carrier can be trimmed if the Object of Function performs the Useful Function itself
- Rule C: Function Carrier can be trimmed if another Component performs its useful function.
  To reduce anticipated difficulty of trimming problems, this Component should have a set of resources necessary to perform the required function. Typical cases:
  1. The Component already performs an identical or similar function on the Object of Function
  2. The Component already performs an identical or similar function on another object
  3. The Component performs any function on the Object of Function or at a minimum simply interacts with the Object of Function

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Trimming. Trimmed Model Table

Function carrier	Action	Object of the function	Category	Rank	Performance	Comments
Ink	pollutes	Water	Harmful			Removed as a Harmful Function
	reflects	Light	Useful	Additional	Insufficient	Moved according to the rule C
Water	moves	Ink	Useful	Auxiliary	Insufficient	Trimmed according to the rule A
Charcoal	scrathes	Ruler	Harmful			Removed as a Harmful Function
	moves	Ink	Useful	Auxiliary	Excessive	Trimmed according to the rule A
	pollutes	Water	Harmful			Removed as a Harmful Function
Oven(incuding heat)	heats	Ruler	Useful	Basic	Excessive	Trimmed according to the rule D
	cures	Ink	Useful	Auxiliary	Excessive	Trimmed according to the rule A
Ruler	holds	Ink	Useful	Auxiliary	Insufficient	
	wears	Charcoal	Harmful			
	reflects	Light	Useful	Additional	Insufficient	reflection of light from the graduations and the chrome
	reflects	Light	Useful	Additional	Insufficient	Moved according to the rule C
Light	informs	Human	Useful	Additional	Insufficient	
Human	moves	Ruler	Useful	Basic	Normal	
	moves	Ink	Useful	Auxiliary	Excessive	

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Key Problem

Key Disadvantage	Key Problem	Source
	How to make "Ruler" perform Function "reflects Light"?	Trimming
	How to change Component "Ruler", in order to eliminate the necessity of performing function "heats Ruler"?	Trimming
Excessive liquid state of ink	How to eliminate Key Disadvantage "Excessive liquid state of ink"?	CECA

Trimming: Algorithm for Creating a Trimming Model

1. Select the Engineering System Component to be trimmed using the selection guidelines
2. Select the first useful function of the Component to be trimmed
3. Select the applicable Trimming rule (Note – Rule A is not recommended for the basic function)
4. If Rule C selected, Select the new Function Carrier
5. Formulate the Trimming problem
6. Repeat steps 2 through 5 for all functions of the Component
7. Repeat steps 1 through 6 for all Components to be trimmed

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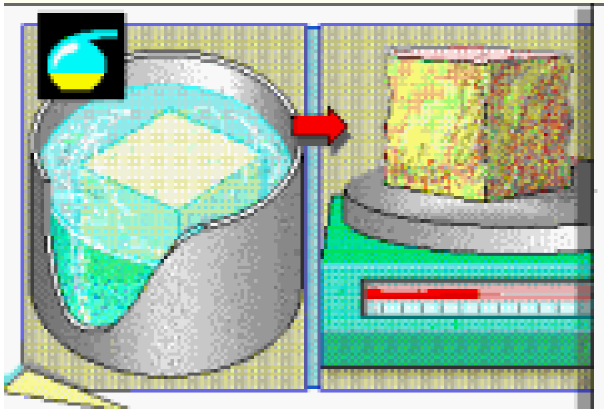
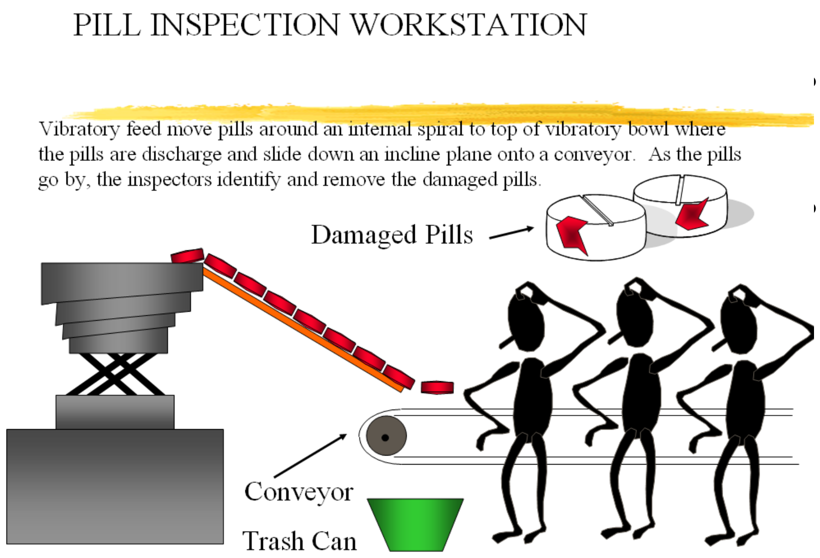
Exercise

- ***Corrosion testing***



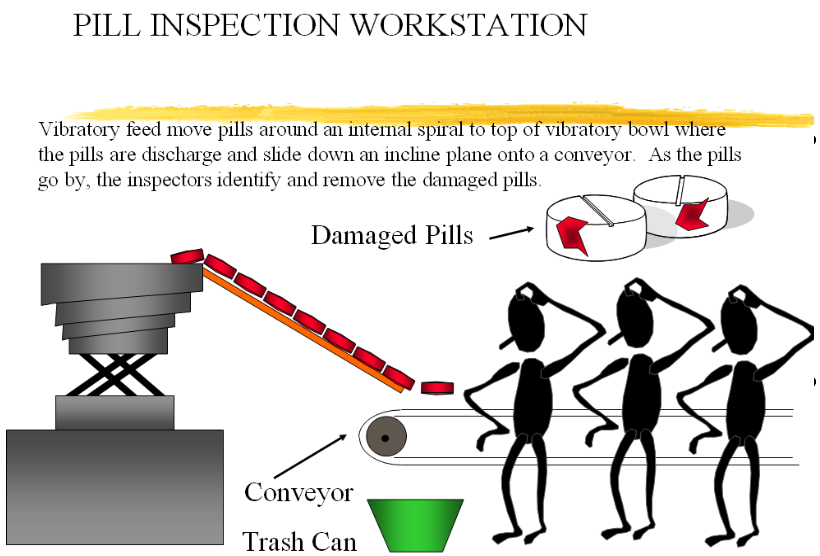
  - *Testing a material's resistance to aggressive mediums (acids) is usually performed by submerging a cube-shaped sample of the material in an acid.*
  - *The acid is held at a fixed temperature for a predetermined length of time, after which the sample is rinsed, dried, and weighed to determine its loss in mass.*
  - *Such tests are usually conducted in platinum vessels because platinum is very resistant to acids.*
  - *Platinum is expensive, however, and thus most testing facilities have only one test vessel.*
  - *As a result, testing must be performed sequentially -- a time-consuming process.*
  - *Problem: How to improve the process?*

Exercise



- A pill manufacturer is faced with a need for cost reduction.
- A labor reduction is required to stay competitive.
- Engineering has evaluated the manufacturing process and determined that by eliminating three inspectors at the end of the production line they can justify an investment of $150,000 for a video inspection system.
- These inspectors are checking for chip damage at on the circumference of the pills (see attached sketch).

Exercise (cont)



- Efforts to correct the damage to the pills during production have been going on for years.
  There are 15 stages of manufacturing and each has been optimized to less than 1% of scrap which exceeds industry standards.
  The video inspection system will provide a 33% return on investment which meets management's financial criteria.
- Unfortunately, money is tight and management has hired your company to find a lower cost solution

FUNCTION ORIENTED SEARCH

Function Oriented Search

- Function oriented search is a problem solving tool based upon identifying existing technologies worldwide using function criteria

- Function oriented search enable us to search for existing technologies that can be effectively adapted to a new domain thus changing the problem from invention to adaptation and also breaks the psychological inertia

- It is best applied on key problems identified after Cause and effect chain analysis or trimming

Algorithm for Function oriented search

1. Identify the key problem to be solved
2. Articulate the specific function to be performed
3. Formulate the required parameters
4. Generalize the function
5. Identify other technologies that perform similar function with a background that to deliver this function it is a matter of life and death
6. Select the technology most suited based on our requirements and constraints
7. Identify and formulate new adaptation problems

Example

- A food company that made some snacks adds some salt to the snacks however with health consciousness going up there was a need for reducing the salt as that would result in sodium reduction, but if the salt was reduced then the food would not taste as good

Example

- The causal chain analysis lead to the root cause that the salty taste delivered is due to the surface area of the salt particle
- This lead to a new problem being formulated that how to have the surface area of salt being large
- Which industry would have a similar function where a small particle needs to have a large surface area?

Example

- Pharmaceuticals industry deal with the same problem
- The new problem formulated was adaptation of this technology for the purpose of increasing the surface area of salt
- That way the salt content was high and also not High
- Depicts that it is very likely that for function would have been delivered in some other industry, we only need to solve adaption problems

Some common Advanced domains

- Military
- Aerospace
- Medicine
- Pharmaceuticals
- Electronics
- Nature

Utilizing scientific Effect databases to narrow Search

The Effects Database has 59 suggestions for Increase Surface Area

Activated Alumina
Activated Carbon
Aerogels
Aerosol
Antifoam
Bubble
Capillary Wave Effect
Ceramic Foam
Cold-forming
Composite Materials
Converse Piezoelectric Effect
Corrugation
Elastic Recovery
Elasticity
Electroactive Polymer
Electrodeposition
Electrostriction
Electrowetting
Ellipse
Extrusion
Ferrofluid
Fin
Fluid Spray
Foam
Folding
Fractal Forms
Groove
Heat Sink
Holes
Hydrophobe
Intumescent Materials
Knurling
Lamella
Metal Foam
Möbius Strip
Nanocomposite
Nanofoam
Nanoporous Material
Nap
Oloid
Origami
Parachute
Plateau-Rayleigh Instability
Porosity
Pressure Drop
Pressure Increase
Reticulated Foam
Rigid Origami
Roller
Rubber Band Thermodynamics
Segmentation
Sonochemistry
Sphericon
Sponge
Spray
Surface Tension
Surfactant
Wear
Zeolite

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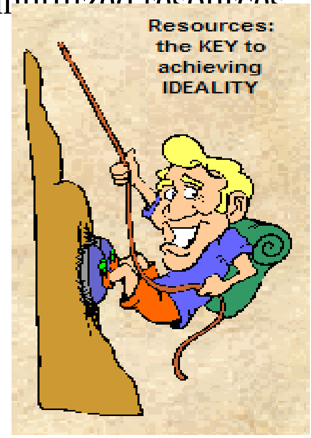
Resources

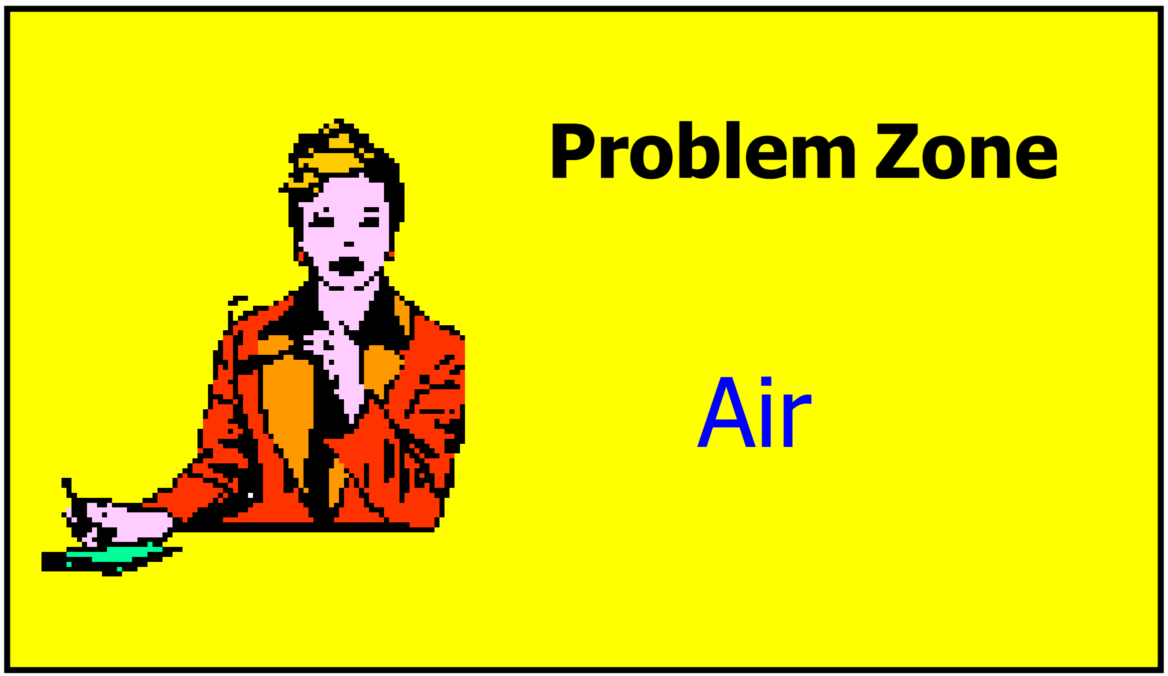
$$\text{Ideality} = \frac{\text{All Useful Functions}}{\text{All Harmful/Undesired Functions + cost}}$$

The concept of inventive resources is closely linked to ideality

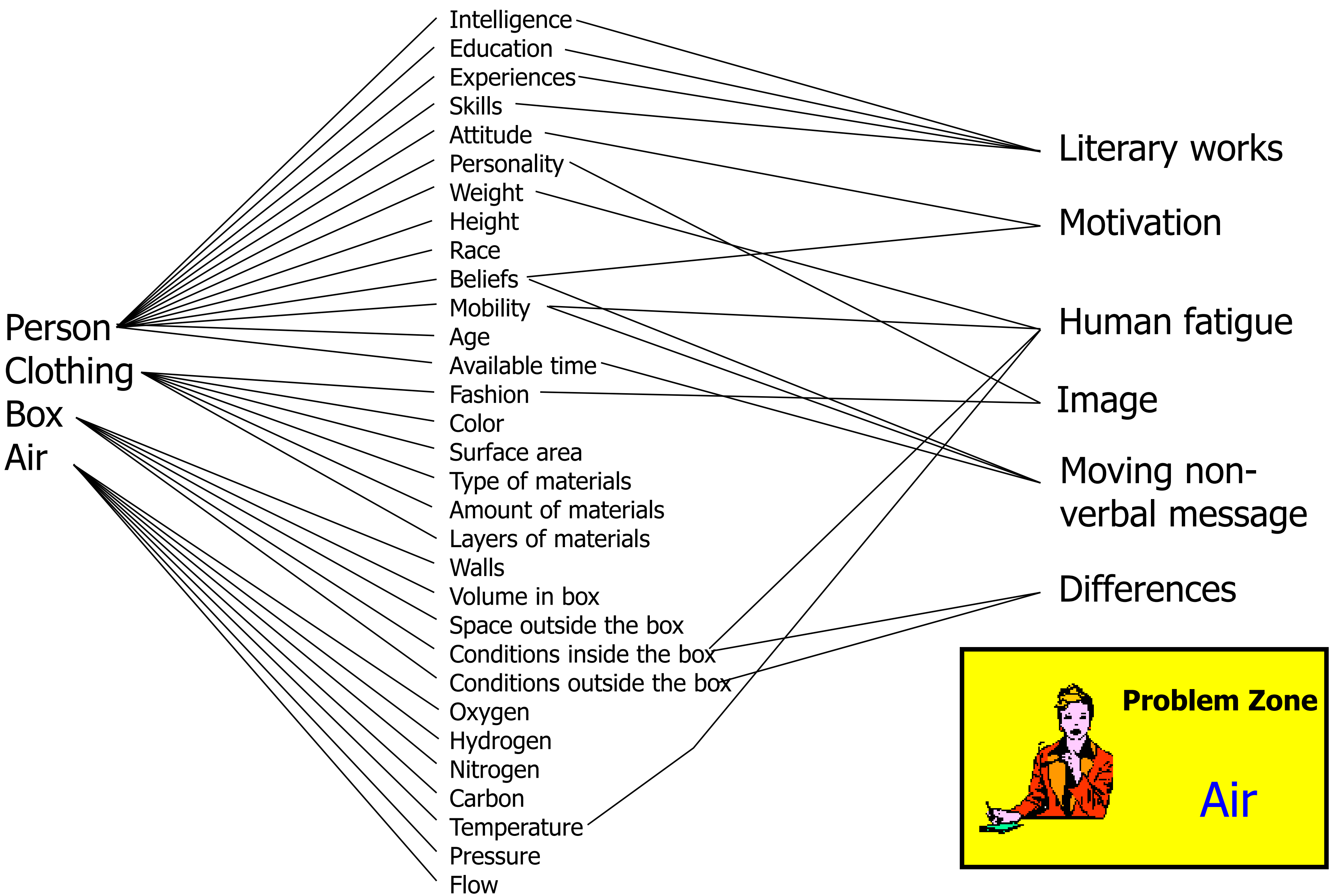
- The utilization of the resources available in a system or its surroundings can increase ideality in several ways:
- Engaging unutilized resources to provide additional useful features (increasing the numerator)
- Reducing cost-related factors (denominator), in particular: - Eliminating unutilized resources
- - Utilizing internal instead of external resources
- - Utilizing less expensive or more accessible resources



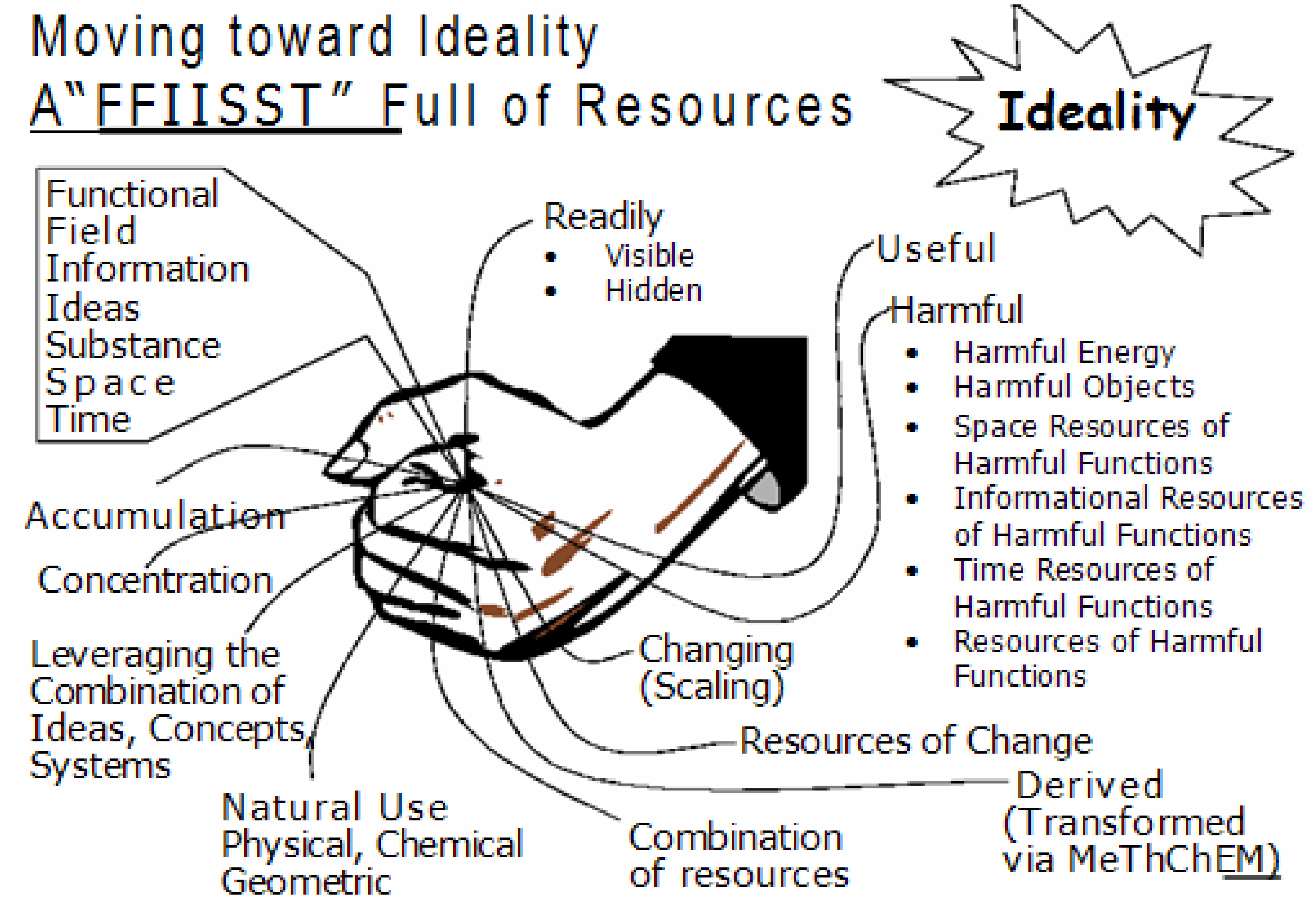
What Resources Are Available in the diagram given below



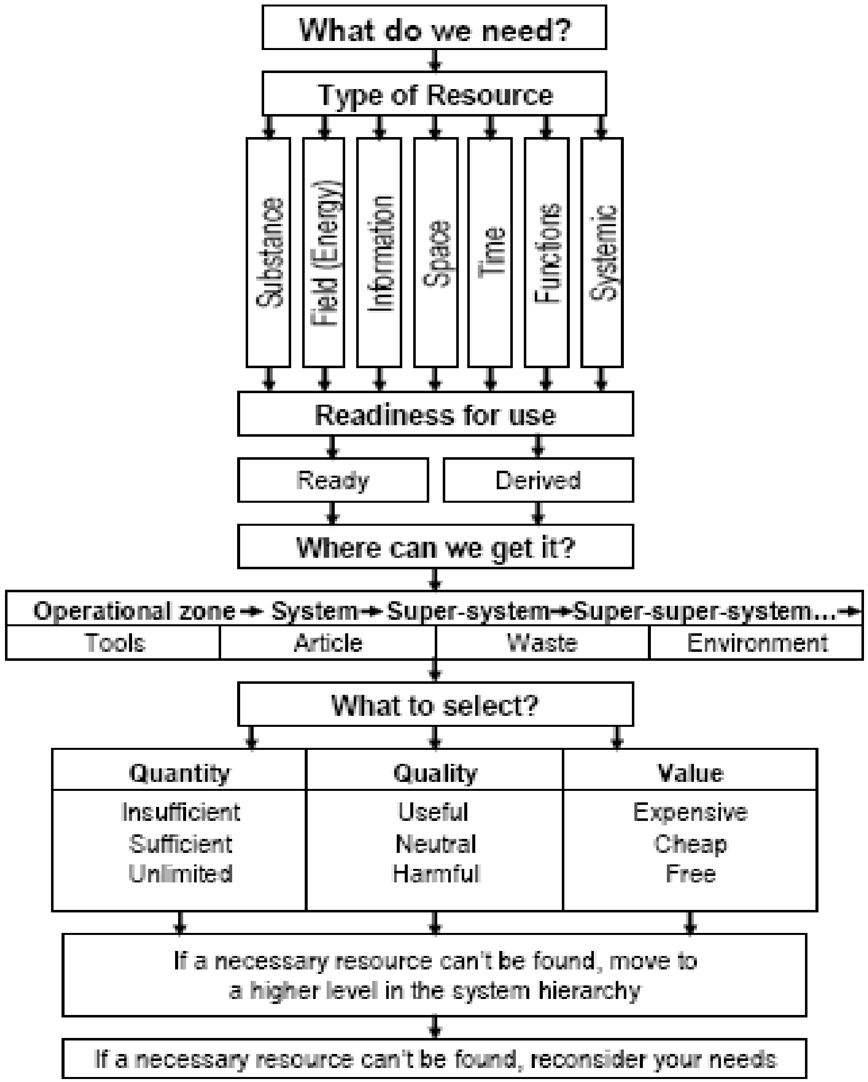
“Derived” Resources: Person Example



- an inventive resource can be defined as:
  - Any substance or anything made of a substance (including waste) that is available in the system or its environment.
  - An energy reserve, free time, unoccupied space, information, etc.
  - The functional and technological ability to perform additional functions, including properties of substances as well as physical, chemical, geometric and other effects.

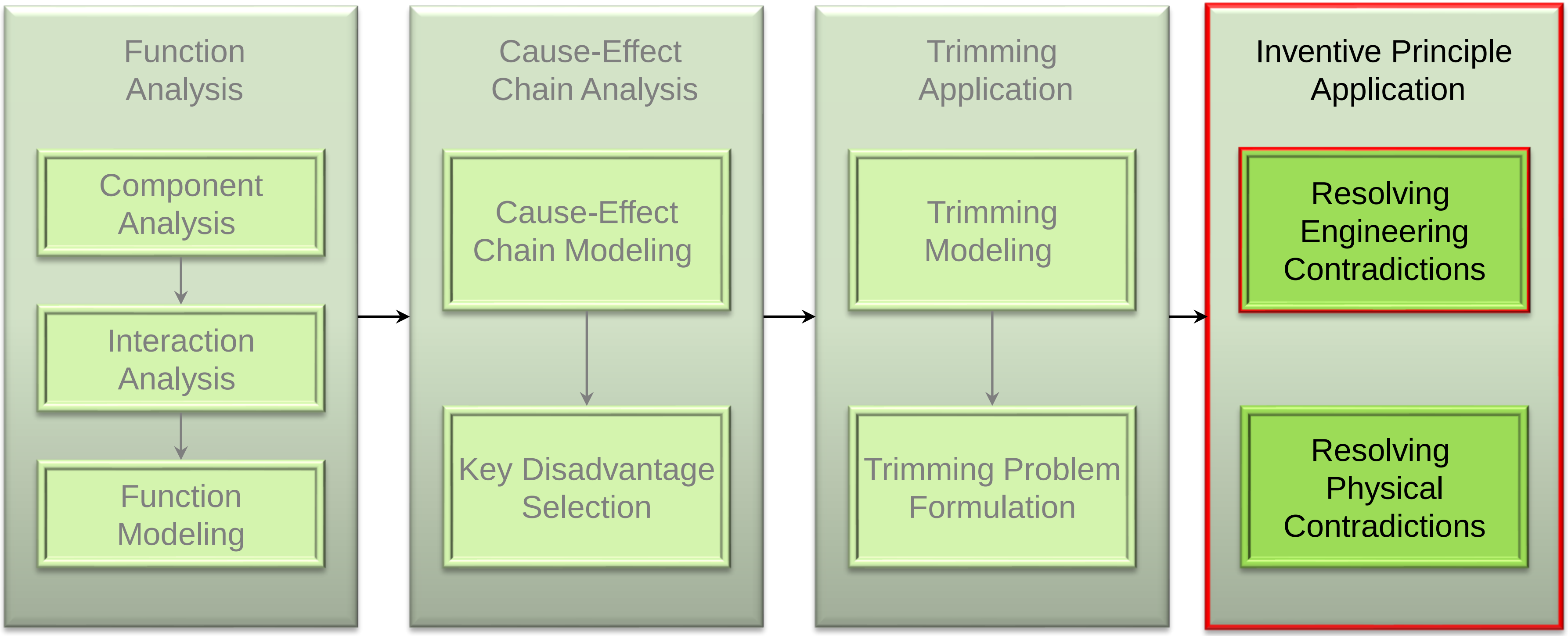

Moving toward Ideality
A "FFIISST" Full of Resources
Ideality
Functional
Field
Information
Ideas
Substance
Space
Time
Readily
• Visible
• Hidden
Useful
Harmful
• Harmful Energy
• Harmful Objects
• Space Resources of Harmful Functions
• Informational Resources of Harmful Functions
• Time Resources of Harmful Functions
• Resources of Harmful Functions
Accumulation
Concentration
Leveraging the Combination of Ideas, Concepts, Systems
Natural Use
Physical, Chemical
Geometric
Changing (Scaling)
Resources of Change
Combination of resources
Derived (Transformed via MeThChEM)

Resource Identification Algorithm



Reference : Resource Algorithm Boris Zlotin

The GEN TRIZ Product Innovation Roadmap



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Example: Table

Definition

An Engineering Contradiction (EC) is a situation, in which an attempt to improve one parameter of an Engineering System leads to the worsening of another parameter

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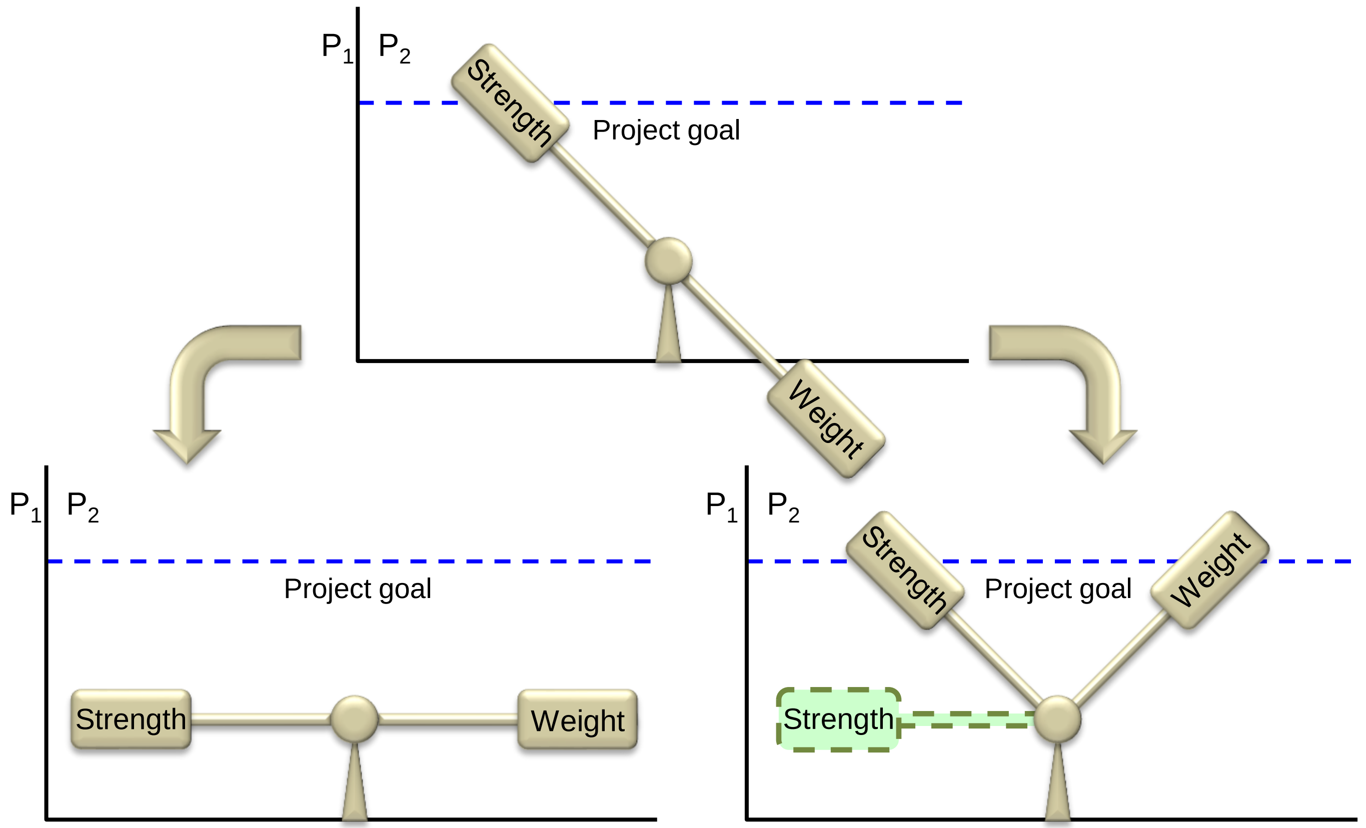
Resolving Engineering Contradictions



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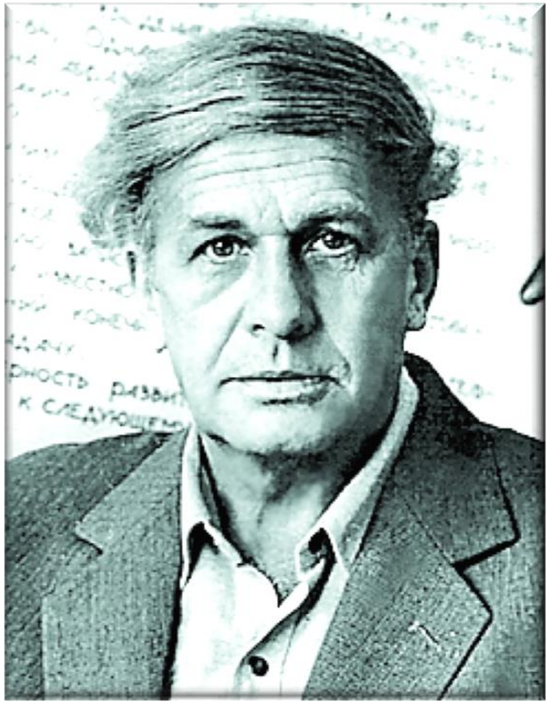
Resolving Engineering Contradictions
What are Altshuller's Findings?

Genrich Altshuller studied the inventive problems and their solutions by analyzing thousands of patents. Key findings are:

- The vast majority of inventive problems are based on Engineering Contradictions
- There are infinitely many problems, but most of them are typical. There are about 1600 typical TP
- All typical TPs are described by the 39th Typical Parameters.
- There are typical solutions of typical tasks - Inventive Principles A total of 40 Principles are known (with about 120 sub-principles)
- For convenience, all Principles are summarized in the Altshuller Matrix



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Engineering Contradictions and Altshuller's Matrix

Improving Parameters

Worsening Parameters

	Weight of a moving object	Weight of a stationary object	Length of a moving object	Length of a stationary object
Shape	8, 10, 29, 40	15, 10, 26, 3	29, 24, 5, 4	13, 14, 10, 7
Stability of composition	21, 35, 2, 39	26, 39, 1, 40	13, 15, 1, 28	37
Strength	1, 8, 40, 35	40, 26, 27, 1	1, 15, 8. 35	15, 14, 28, 26
Time of action of a moving object	19, 5, 34, 31	-	2, 19. 9	-
Time of action of a stationary object	-	6, 27, 19, 16	-	1, 40, 35

Inventive Principles

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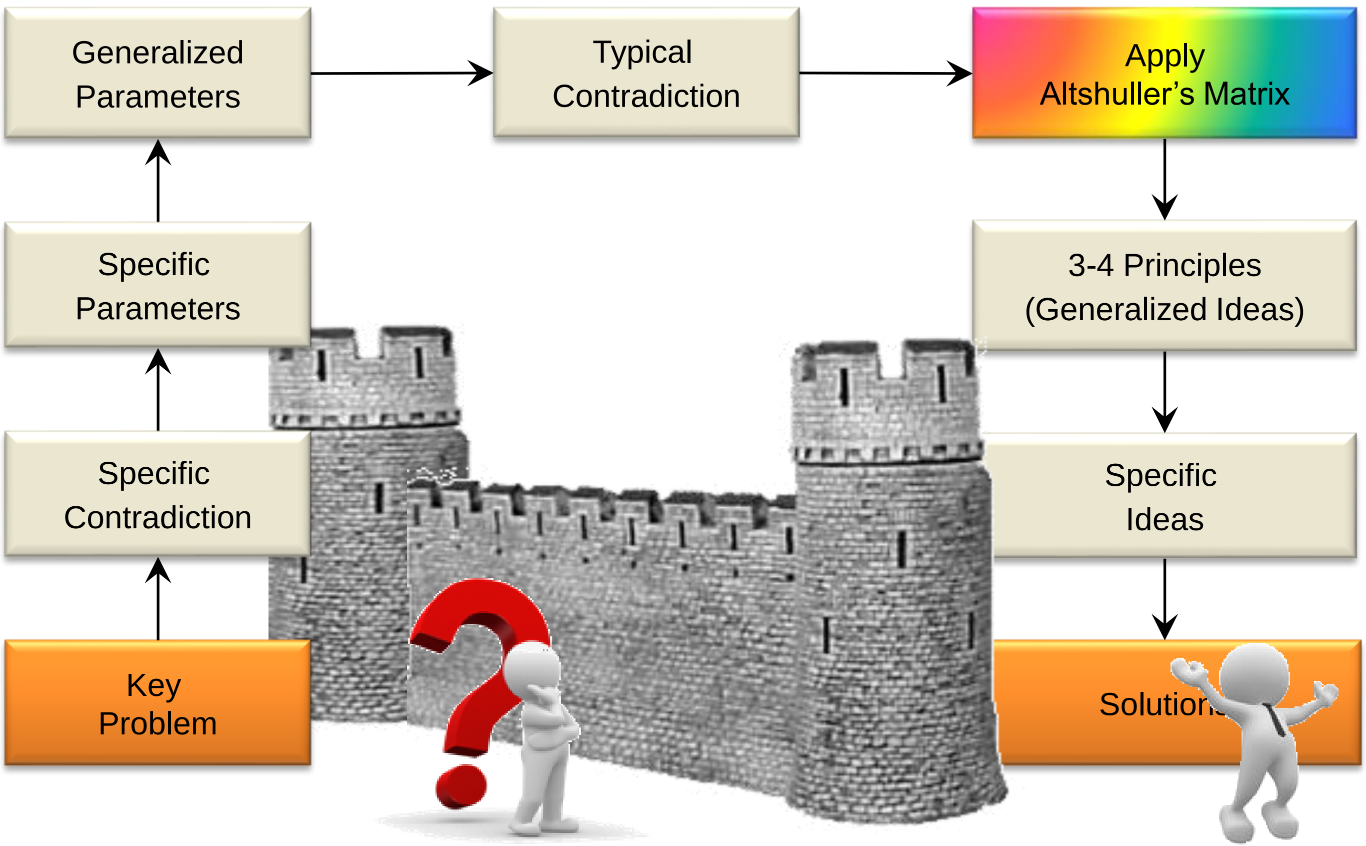
Resolving Engineering Contradictions: Process



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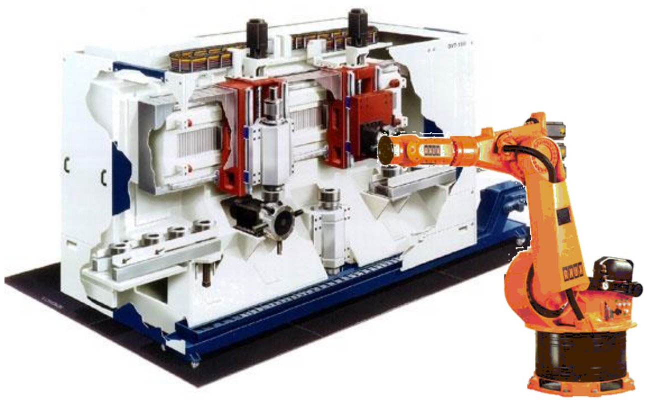
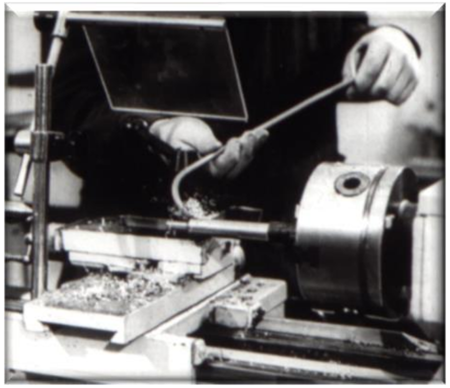
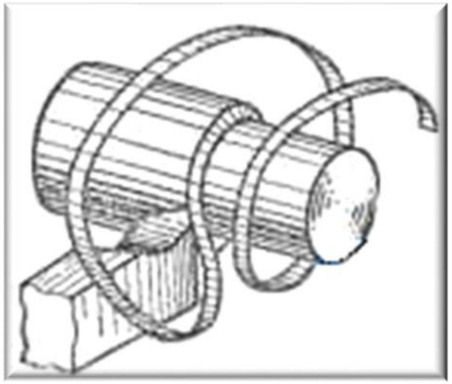
Resolving Engineering Contradictions
Example: Turning Machine







Key Problem

Increase the process stability by constantly removing chips from the turning machine without complex and expensive special robot application

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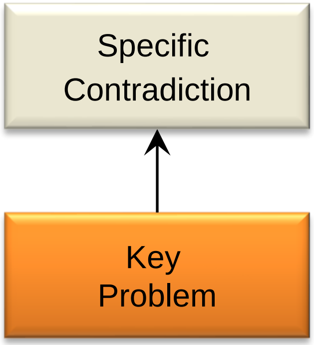
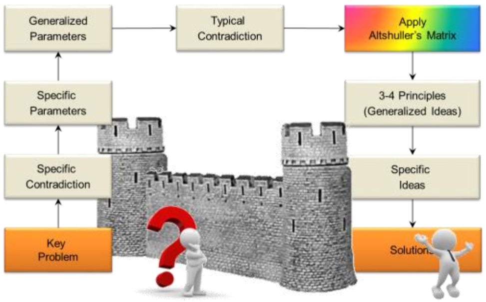
Resolving Engineering Contradictions: Formulating the Engineering Contradiction

Inventive Problems are written in the form of “IF - THEN – BUT”

	Engineering Contradiction
IF	We use special robot for image recognition
THEN	the shaving would be removed and the process would be stable
BUT	the applied equipment would be extremely complex (and expensive)





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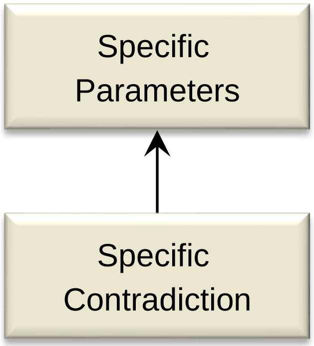
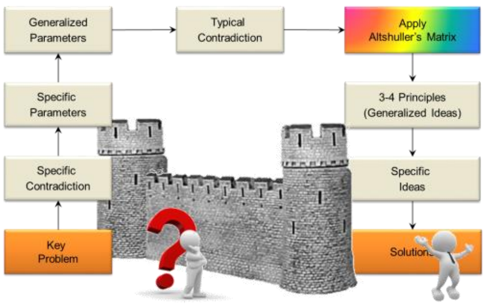
Resolving Engineering Contradictions: Identification of Specific Parameters

Identify the parameters in the Engineering Contradiction

	Parameters in the Contradiction
Improving Parameter	Process stability
Worsening Parameter	Robot complexity





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Resolving Engineering Contradictions:
Identification of Typical Parameters

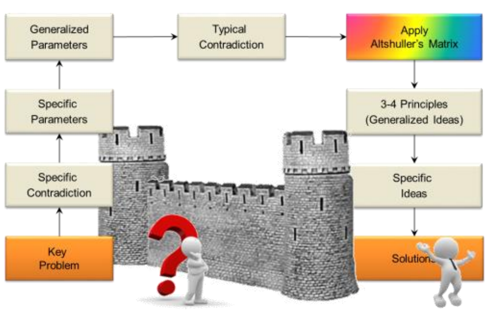
Identify from Altshuller's list those Typical Parameters that are similar in meaning to the Specific Parameters or are derivatives of Specific Parameters

	Specific Parameter	Typical Parameter
Improving Parameter	Process stability	Reliability
Worsening Parameter	Robot complexity	Complexity of Device

Generalized Parameters

↑

Specific Parameters



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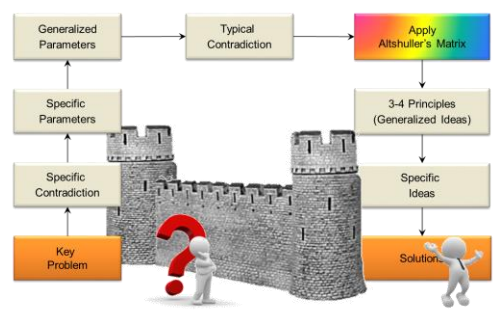
Resolving Engineering Contradictions:
Identification of Applicable Inventive Principles

	Adaptability	Complexity of device	Complexity of control	Level of automation
Waste of time	35,28	6,29	18,28,32,10	24,28,35,30
Amount of substance	15, 3, 29	3, 13, 27, 10	3, 27, 29, 18	8, 35
Reliability	13, 35, 8, 24	13, 35, 1	7, 40, 28	11, 13, 27
Accuracy of measurement	13, 35, 22	27, 35, 10, 34	26, 24, 32, 28	28, 2, 10, 34
Accuracy of manufacturing	-	26, 2, 18	-	26, 28, 18, 23

Apply
Altshuller's Matrix

↓

3-4 Principles
(Generalized Ideas)



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Resolving Engineering Contradictions:
Description of Inventive Principles

Number	Name	Description of Inventive Principles
13	Other way around	• Invert the action (s) used to solve the problem (e.g., instead of cooling an object, heat it). • Make movable parts (or the external environment) fixed, and fixed parts movable. • Turn the object (or process) 'upside down'.
35	Change physical or chemical properties	• 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.
1	Segmentation	• Divide an object into independent parts. • Make an object easy to disassemble. • Increase the degree of fragmentation or segmentation.

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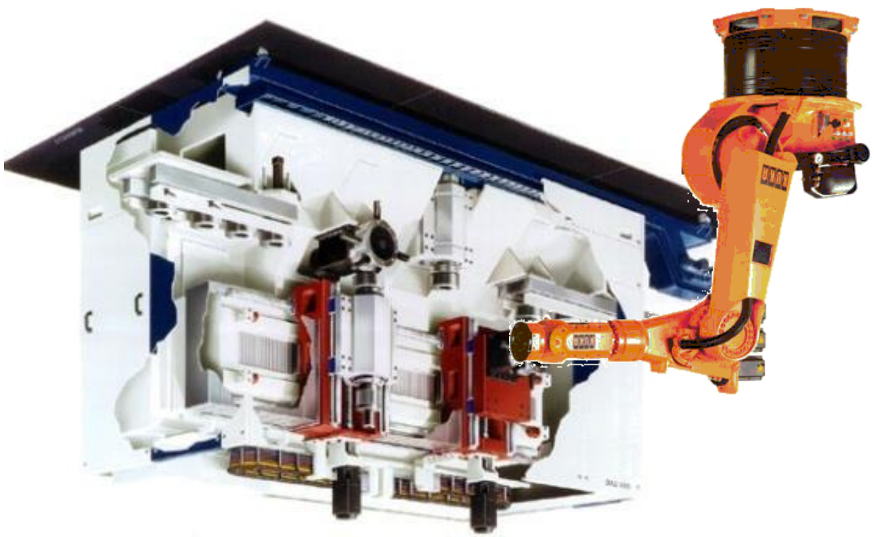
Resolving Engineering Contradictions:
Identifying the Specific Solutions

Locate the turning machines and serving robots in an 'upside down' position. By doing so, the shavings will fall down from the machine by themselves without any additional effort. Fully automatic unmanned turning machines and serving robots can work in such position without any problems.

This solution was developed and implemented in Japan.



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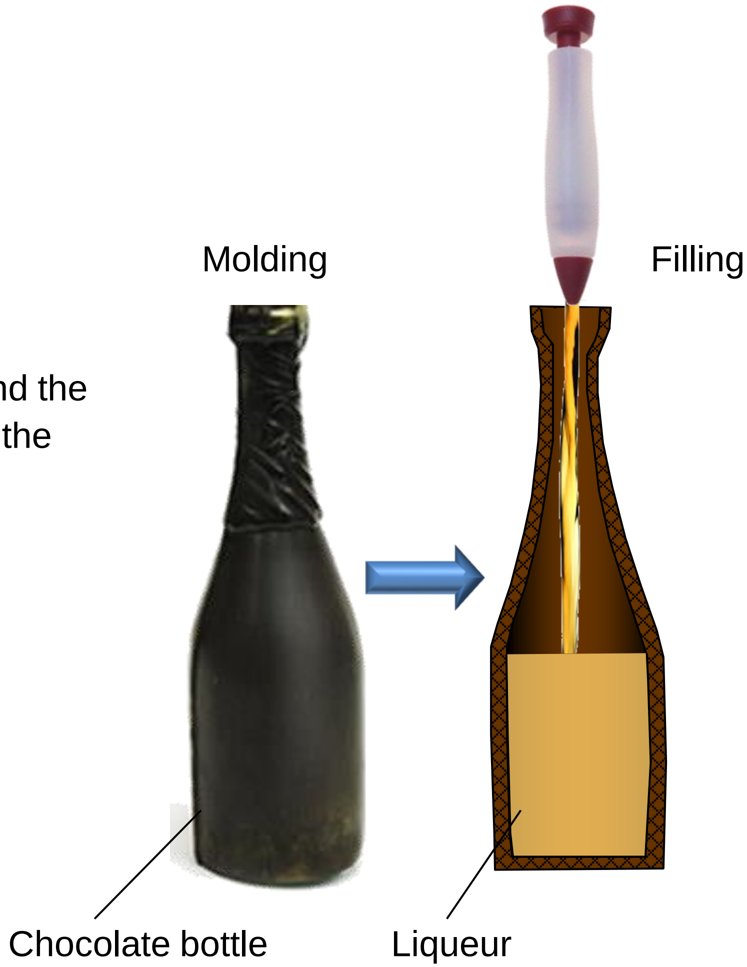
Resolving Engineering Contradictions
Example: Chocolate Bottle Candy

- Engineering system to be analyzed:
  - The candy filling process
- Main function:
  - To fill chocolate candy bottles with liqueur
- Challenge:
  - The filling process is inefficient. Cold liqueur is viscous and the filling process is slow. Hot liqueur is more fluid, but melts the chocolate bottle
- Project goal:
  - Increase productivity and protect the chocolate bottle



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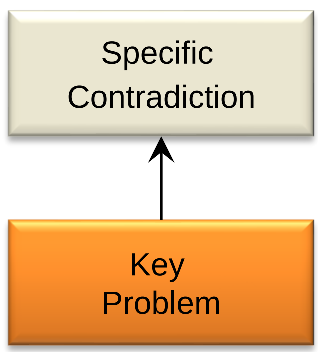
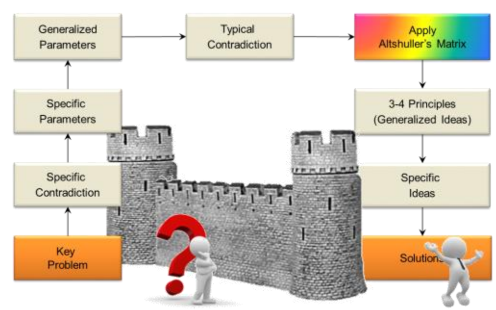
Resolving Engineering Contradictions:
Formulating the Engineering Contradiction

Inventive Problems are written in the form of “IF - THEN – BUT”

	Engineering Contradiction
IF	If the liqueur is hot
THEN	it can be poured quickly
BUT	It can damage the chocolate bottle





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Resolving Engineering Contradictions: Identification of Specific Parameters

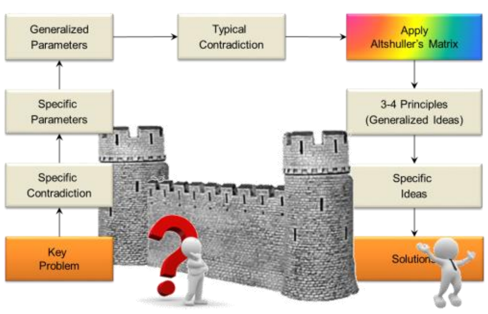
Identify the parameters in the Engineering Contradiction

	Parameters in the Contradiction
Improving Parameter	Manufacturing productivity
Worsening Parameter	Damage of the chocolate bottle

Specific Parameters

↑

Specific Contradiction



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Resolving Engineering Contradictions: Identification of Typical Parameters

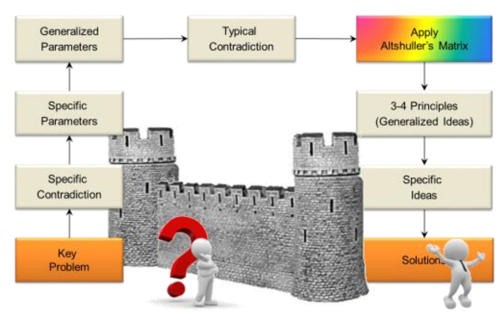
Identify from Altshuller’s list those Typical Parameters that are similar in meaning to the Specific Parameters or are derivatives of Specific Parameters

	Specific Parameter	Typical Parameter
Improving Parameter	Manufacturing productivity	Capacity/productivity
Worsening Parameter	Damage of the chocolate bottle	Harmful factor acting from outside

Generalized Parameters

↑

Specific Parameters



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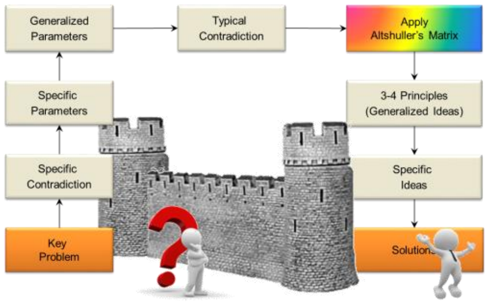
Resolving Engineering Contradictions:
Identifying Applicable Inventive Principles

	Accuracy of measurement	Accuracy of manufacturing	Harmful factor acting from outside	Harmful factor developed by an object
Adaptability	13, 35, 2	-	35, 11, 22, 31	-
Complexity of a device	27, 35, 10, 34	26, 2, 18	22, 19, 29, 40	19, 1, 31
Complexity of control	26, 24, 32, 28	-	22, 19, 29, 40	2, 21, 27, 1
Level of automation	28, 2, 10, 34	26, 28, 18, 23	33, 3, 34	2
Capacity/productivity	10. 34, 28, 32	10, 18, 32, 39	22, 35, 13, 24	22, 35, 18, 39

Apply
Altshuller's Matrix

↓

3-4 Principles
(Generalized Ideas)



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Resolving Engineering Contradictions: Description of the Inventive Principles

Name	Description of Inventive Principles
22. “Blessing in disguise”	• Use harmful factors (particularly, harmful effects of the environment or surroundings) to achieve a positive effect • Eliminate the primary harmful action by adding it to another harmful action, to resolve the problem • Amplify a harmful factor to such a degree that it is no longer harmful
35. Change physical or chemical properties	• 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
13. Other way around	• Invert the action (s) used to solve the problem (e.g., instead of cooling an object, heat it) • Make movable parts (or the external environment) fixed, and fixed parts movable • Turn the object (or process) 'upside down'
24. “Intermediary”	• Use an intermediary carrier article or intermediary process • Merge one object temporarily with another (which can be easily removed)

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Resolving Engineering Contradictions
Solution

- The idea is to freeze the liqueur in a bottle-shaped mold, and then pour melted chocolate over with the frozen liqueur
- The solution is simple and very effective

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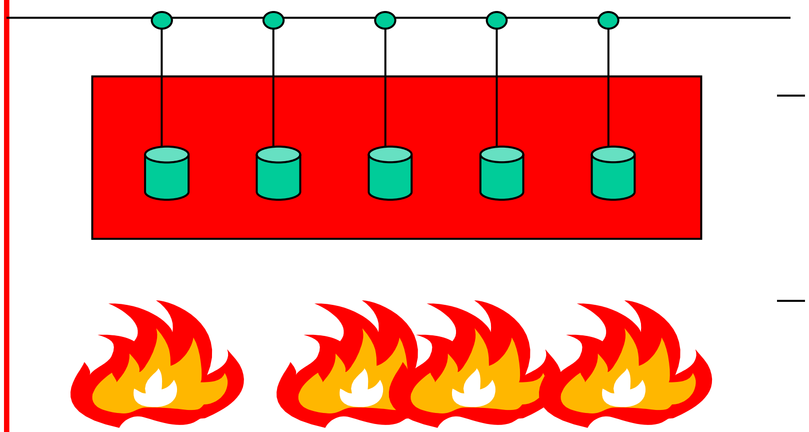
Check contradiction

- Do the If statements contain actions that we can control?
- Are the two statements exactly opposite?
- Are the two statements in exaggerated state?
- Are the resultants reversing?
- Do the resultants contain functional language?
- Is it terminology free?

Resolving EC

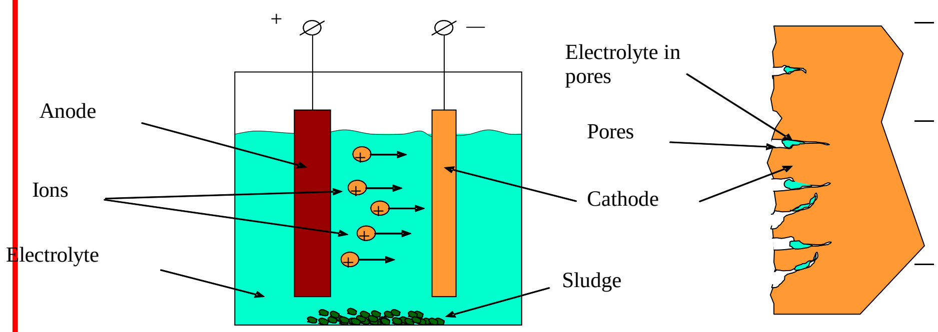
Engineering Contradiction	Improving Parameter (Specific)	Improving Parameter (Generalized)	Worsening Parameter (Specific)	Worsening Parameter (Generalized)	Recommended Inventive Principle0	Chosen Inventive Principles	Solution
IF Ink is used THEN graduations are black BUT very complex process		- $		- $	-	-	
IF Ink is not used THEN no complexity of process BUT graduations are not black	complexity of process	Manufacturability	defects	Loss of a substance	15. Dynamics 34. Discarding and recovering 33. Homogeneity	33. Homogeneity	Make the chrome graduations black by themselves

Exercise: Formulation of Technical Contradictions, TC-1 and TC-2



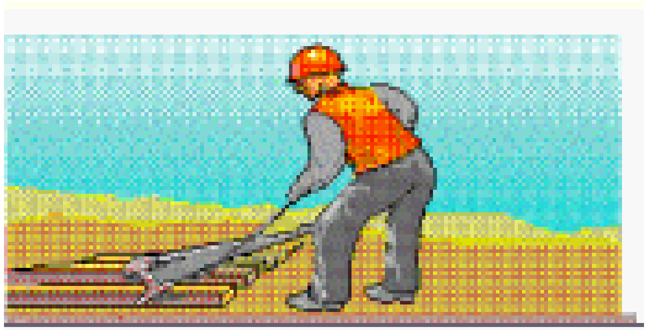
- **Problem 1:**
  - Metal surfaces are chemically coated as follows: the metal work piece is placed in a bath filled with a metal salt solution (e.g. nickel, cobalt, etc.).
  - During the ensuing reduction reaction, metal from the solution precipitates onto the surface of the work piece.
  - The higher the temperature, the faster the process takes place; however, at high temperatures the solution decomposes, and up to 75% of the chemicals are lost through settling on the bottom and sides of the bath.
  - Adding stabilizers is not effective, and conducting the process at a low temperature sharply decreases production.

Exercise: Formulation of Technical Contradictions, TC-1 and TC-2



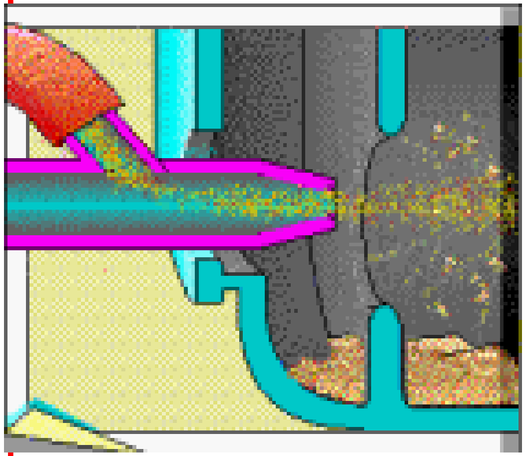
- **Problem 2**:
  - In the electrolytic process by which pure copper is produced, a small amount of electrolyte liquid remains in the pores on the surface of copper sheets.
  - When the copper is stored the electrolyte evaporates, creating oxide spots on the surface which reduces the value of the copper and results in substantial losses.
  - The best way to solve the problem was to avoid producing the pores in the first place.
  - This approach was immediately rejected, however, because it required substantially reducing the d-c current, which would dramatically reduce productivity.
  - Instead, they decided to reduce the financial losses by washing the sheets of copper prior to storage to remove the electrolyte from the pores.
  - This was not only costly but inadequate, and attempts at improving the washing process continued for over 15 years.

Exercise



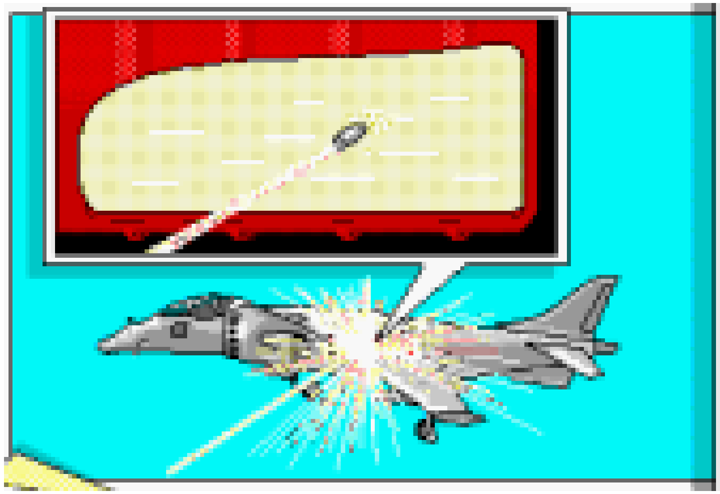
- You may have seen the workers move a heavy rail.
- Several people hook and turn the rail over with the bars all together.
- Then they again hook it and turn.
- The work is hard and dangerous: if a worker looses concentration then at the time of rolling the rails the rails can have a spring action and this can hurt workers
- This is a problem: how to help the workers?

Exercise



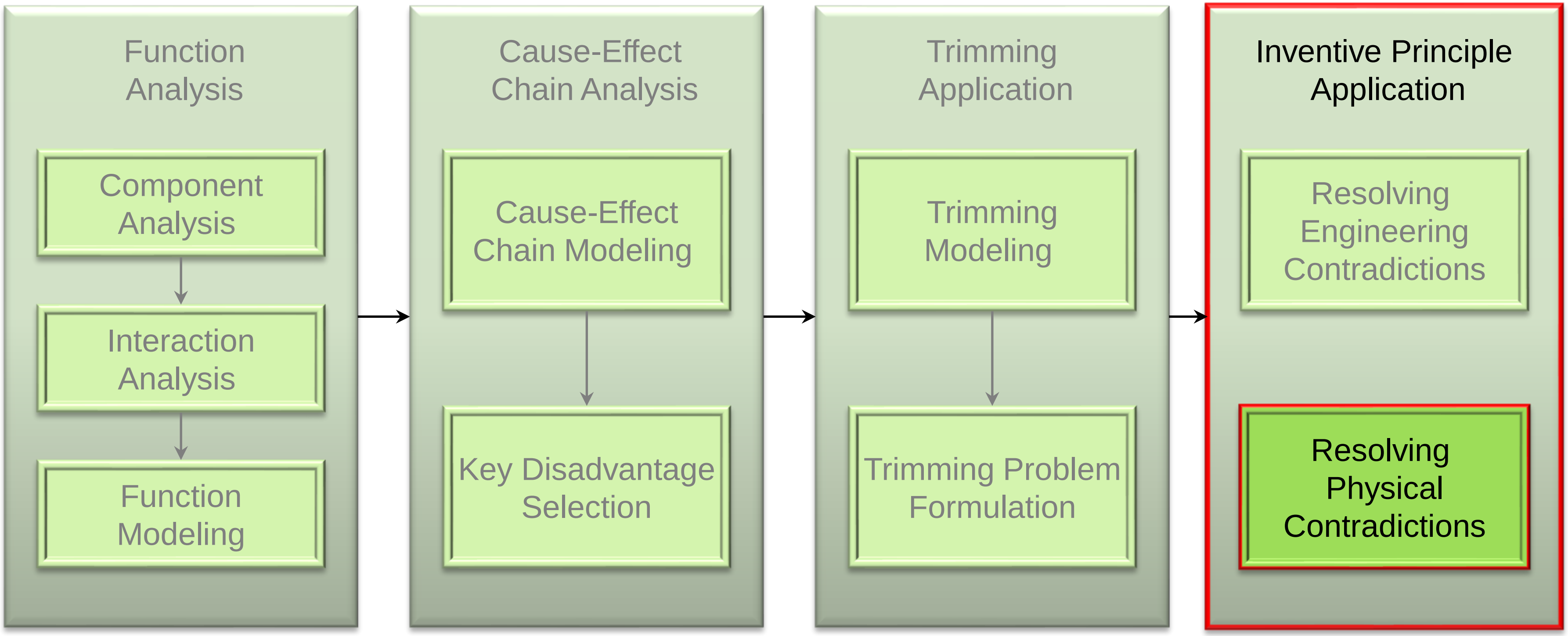
- A shop for production of molded plastic parts of intricate shapes was set up at a factory.
- The method of their finishing treatment caused certain difficulties.
- The inner surface of molded pieces needed polishing and removal of the molded particles stuck to the plastic.
- A strong air stream with abrasive particles (e.g., sand) was used for this purpose: the whirl of particles “licked off” all the roughness and dirt.
- However, afterwards the inner cavities and crevices were filled up with smoothing materials which had to be shaken out.
- An attempt was made to use steel grit for blasting and later use magnets for removal but the operation only slightly improved at the expense of the time spent to remove all the grit.
- What can be done?

Exercise



- During World War II to target appropriate locations the airplane had to fly very low.
- However when it flew low there was also the risk of the enemy bullets hitting the fuel tanks and the plane running out of fuel, also leaking fuel presented a potential fire hazard
- How could you solve this problem

The GEN TRIZ Product Innovation Roadmap



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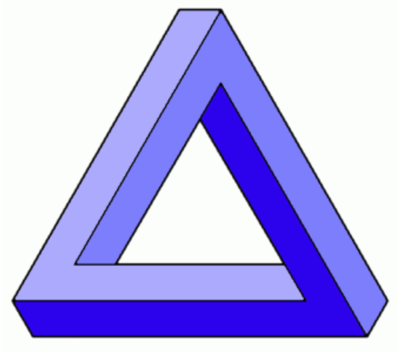
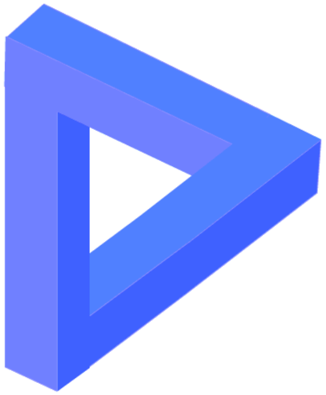
Resolving Physical Contradictions





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Resolving Physical Contradictions: Definition

- A Physical Contradiction is two justified opposite requirements placed upon a single physical parameter of an object
- These requirements are caused by the conflicting requirements of an Engineering Contradiction

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Resolving Physical Contradictions: Example

The hammer has to be heavy (has a high weight) *to drive in nails effectively*, BUT **the hammer** has to be light (has a low weight) *to make it easy to operate*.

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Ways of Resolving Physical Contradictions

- Separating Contradictory Demands
  - Separation in Space (key question “where?”)
  - Separation in Time (key question “when?”)
  - Separation in Relation (key question “for whom?”)
  - Separation in Direction (key question “in what direction?”)
  - Separation in System Level (no key question)
- Satisfying Contradictory Demands
- Bypass

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Resolving Physical Contradictions
Separation in Space

If two contradictory demands are required at different locations within an engineering system, separate the contradictory demands

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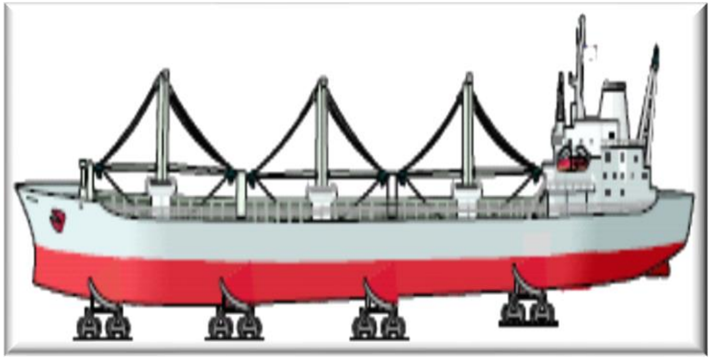
Resolving Physical Contradictions
Example: Ship and Cart

- The ship moves on special carts on rails
- The water near the shore is very dirty, so dirt gets into the bearings
- After returning to the shore, the carts have to be disassembled and washed, and then assembled again
- The wheels are big, there are a lot of carts, so the process is long, complicated and expensive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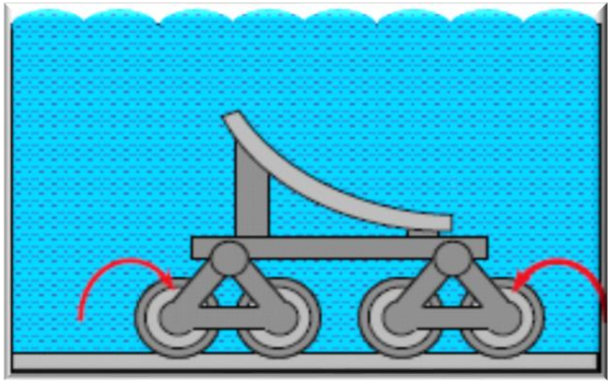
Resolving Physical Contradictions
Example: Ship and Cart

- Engineering System:
  - Cart
- Physical Contradiction:
  - The cart has to be above the water level to prevent contamination of bearings, BUT
  - The cart has to be below the water level to in order to move the ship into the water
- Resolving Method:
  - Both requirements apply to different areas of space (only the wheels should be above the water level and the rest of the cart should be below the water level) => the separation in space is available



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Resolving Physical Contradictions: Recommended Inventive Principles

- Principle 1 — Segmentation
- Principle 2 — Taking out
- Principle 3 — Local quality
  - Change an object's structure from uniform to non-uniform, change the external environment (or external influence) from uniform to non-uniform
  - Make each part of an object function in conditions most suitable for its operation
  - Make each part of an object fulfill a different and useful function
- Principle 7 — “Nested doll”
- Principle 4 — Asymmetry
- Principle 17 — Another dimension

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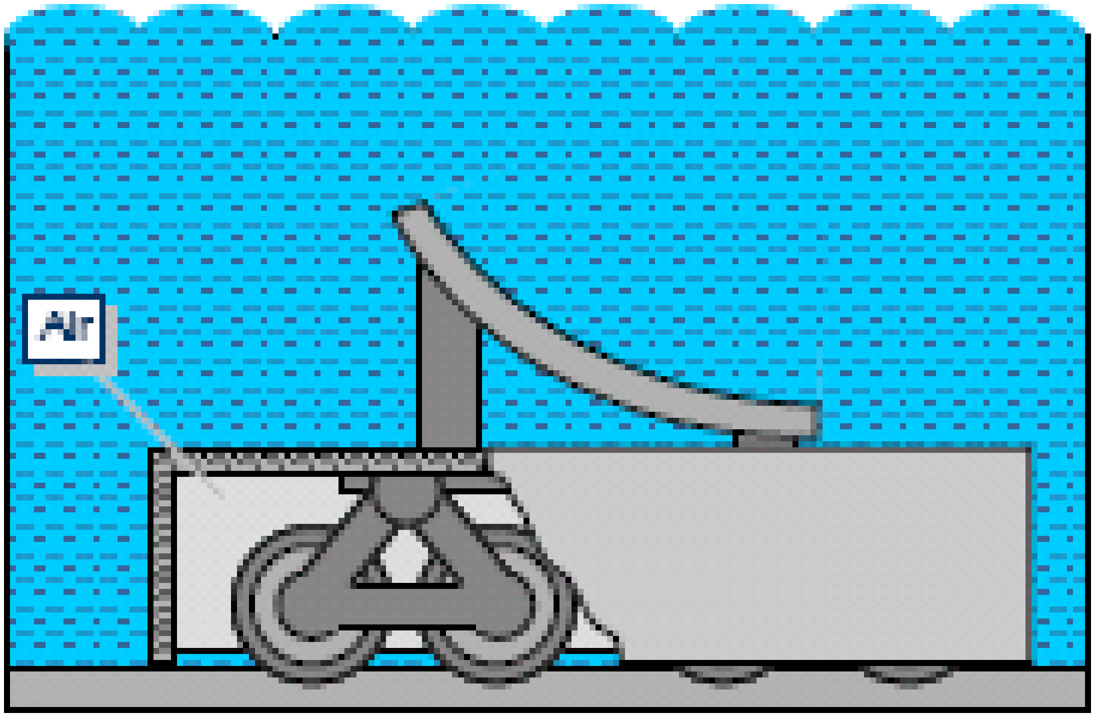
Resolving Physical Contradictions
Solution

Another example



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Ways of Resolving Physical Contradictions

- Separating Contradictory Demands
  - Separation in Space (key question “where?”)
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  - Separation in Relation (key question “for whom?”)
  - Separation in Direction (key question “in what direction?”)
  - Separation in System Level (no key question)
- Satisfying Contradictory Demands
- Bypass

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Resolving Physical Contradictions: Separation in Time

If the contradictory demands are required at different times, separate them using ‘Separation in Time’ method

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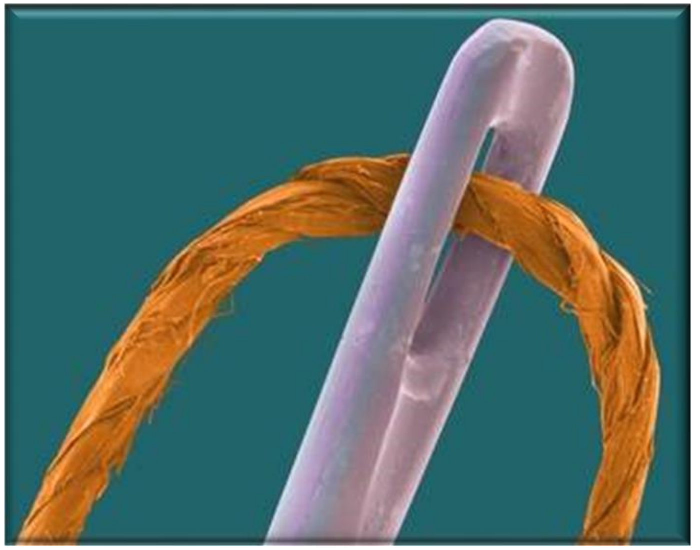
Resolving Physical Contradictions:
Example: Eye of the Needle

- Engineering System:
  - Needle
- Physical Contradiction:
  - The eye of the needle should be large for directing the thread easily into it, BUT
  - The eye of the needle should be small to avoid damage to the clothes
- Resolving Method:
  - Both requirements apply to the same area of space => the separation in space is not applicable
  - Both requirements apply to different moments => the separation in time is applicable (needle eye should be large before sewing, and it should be small while sewing)



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Resolving Physical Contradictions: Recommended Inventive Principles

- Principle 9 — Preliminary anti-action
- Principle 10 — Preliminary action
- Principle 11 — In-advance “cushioning”
- Principle 15 — Dynamics
- Principle 34 — Discarding and recovering

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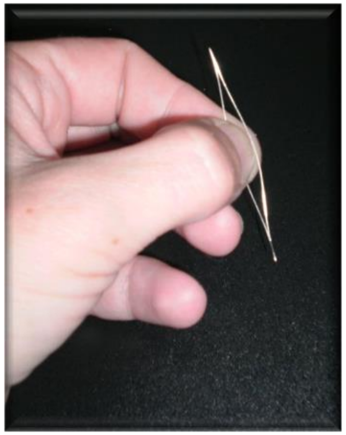
Resolving Physical Contradictions
Solutions

Another example

Inventive Principle “Dynamics’”

- Allow (or design) the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition
- Divide an object into parts capable of movement relative to each other
- If an object (or process) is rigid or inflexible, make it movable or adaptive



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Ways of Resolving Physical Contradictions

- Separating Contradictory Demands
  - Separation in Space (key question “where?”)
  - Separation in Time (key question “when?”)
  - Separation in Relation (key question “for whom?”)
  - Separation in Direction (key question “in what direction?”)
  - Separation in System Level (no key question)
- Satisfying Contradictory Demands
- Bypass

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Resolving Physical Contradictions
Separation in Relation

If the contradictory demands are required for different components, separate them using “Separation in Relation” method

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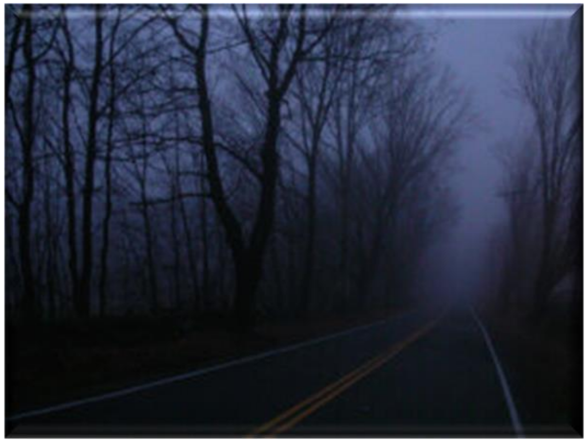
Resolving Physical Contradictions
Example: Driving at night



- Engineering System:
  - Headlights
- Physical Contradiction:
  - The headlights should be bright to provide a good visibility of road objects for the car driver, BUT
  - The headlights should be dim to avoid blinding of other drivers
- Resolving Method:
  - Both requirements apply to the same area of space and moment of time => neither separation in space, nor in time, are not applicable
  - Both requirements apply to different objects (the car driver and opposite drivers) => the separation in relation is applicable

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Resolving Physical Contradictions
Recommended Inventive Principles

- Principle 3 — Local quality
- Principle 17 — Another dimension
- Principle 19 — Periodic action
- Principle 31 — Porous materials
- Principle 32 — Optical properties changes
  - Change the color of an object or its external environment
  - Change the transparency of an object or its external environment
  - Use well-visible additives
- Principle 40 — Composite material

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Resolving Physical Contradictions
Solution

Another example

- Detect live objects (humans or animals) by using infrared (IR) light invisible for drivers:
  - Use an IR illuminator and compatible IR detector or camera configured to detect IR light reflected from objects in front of the car
  - The IR camera can output a video signal to a display, such as a head-up display, to provide an enhanced view of the approaching environment to the driver.
    US Patent 7,217,020 “Headlamp assembly with integrated infrared illuminator” by General Motors Corporation

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Ways of Resolving Physical Contradictions

- Separating Contradictory Demands
  - Separation in Space (key question "where?")
  - Separation in Time (key question "when?")
  - Separation in Relation (key question "for whom?")
  - Separation in Direction (key question "in what direction?")
  - Separation in System Level (no key question)
- Satisfying Contradictory Demands
- Bypass

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Resolving Physical Contradictions
Separation in Direction

If the contradictory demands are required for different directions , separate them using ‘Separation in Direction’ method

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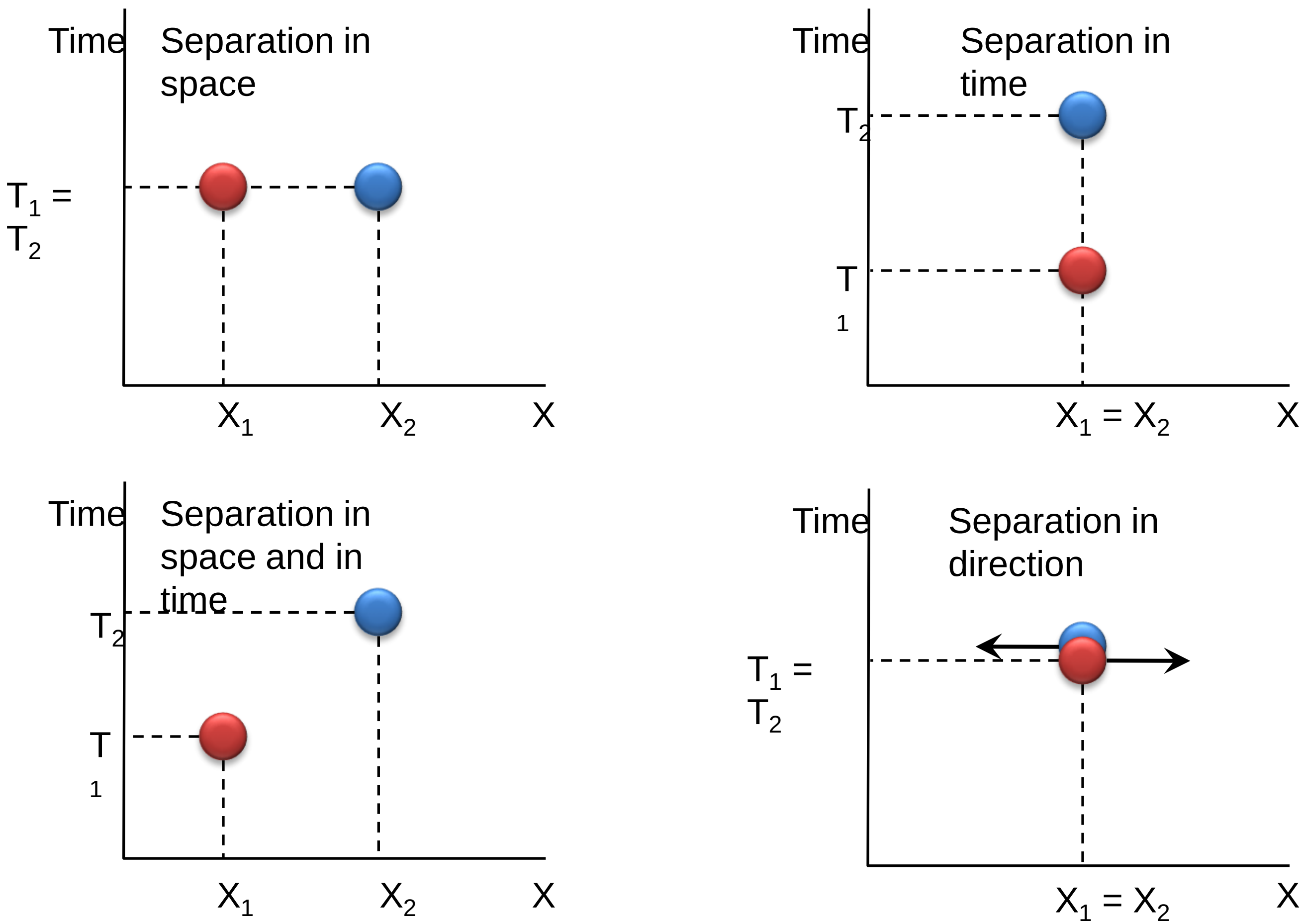
Theoretical Base



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Separation in Direction
Associating Inventive Principals

- Asymmetry
- Composite Materials
- Parameter Changes
- Curvature
- Another Dimension
- Color Changes

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Separation in Direction
Example: Wrench

- A wrench head should be retaining to rotate a nut, BUT it should not be retaining to release a nut

- Separation in time:
  The wrench head is retaining when it is necessary to rotate a nut, and it is not retaining when it is necessary to release a nut
- Inventive Principle: Dynamization (divide an object to parts moving relatively each other)
- Solution: Channel lock wrench

- Separation in direction:
  The wrench head is retaining in direction of rotation, and it is not retaining in direction of releasing
- Inventive Principle: Asymmetry (make a system asymmetrical)
- Solution: Asymmetrical wrench

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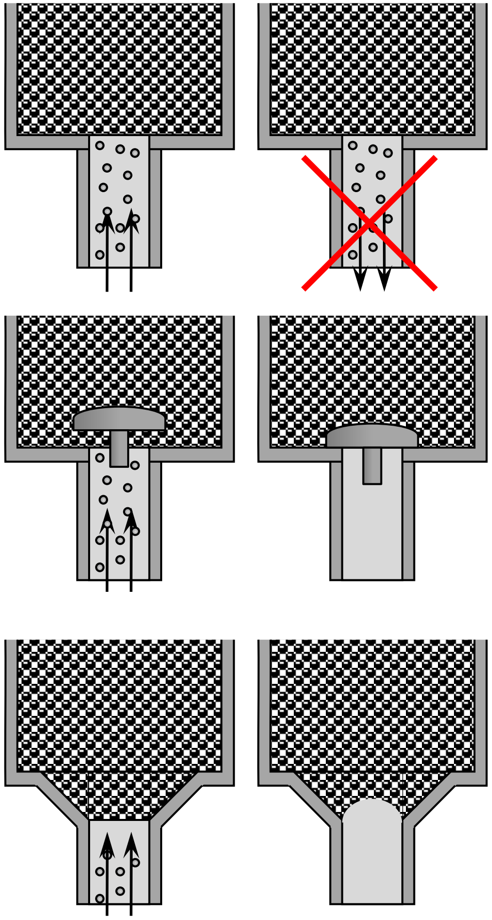
Separation in Direction
Example: Fertilizer Dryer

- Physical Contradiction:
  - The nozzle should conduct granules to supply the dryer, BUT it should not conduct granules to prevent granules spill
- Separation in time:
  - The nozzle is open when it is necessary to supply the dryer, and it is closed when it is necessary to prevent granules spill
- Inventive Principle: Dynamization (divide an object to parts moving relatively each other)
- Solution: A plug
- Separation in direction:
  - The nozzle conducts granules in straightforward direction, and it does not conduct granules in opposite direction
- Inventive Principle:
  - Curvature (make a system curved)
- Solution: Conical nozzles



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Ways of Resolving Physical Contradictions

Ways of Resolving Physical Contradictions:

- Separating Contradictory Demands
  - Separation in Space (key question “where?”)
  - Separation in Time (key question “when?”)
  - Separation in Relation (key question “for whom?”)
  - Separation in Direction (key question “in what direction?”)
  - Separation in System Level (no key question)
- Satisfying Contradictory Demands
- Bypass

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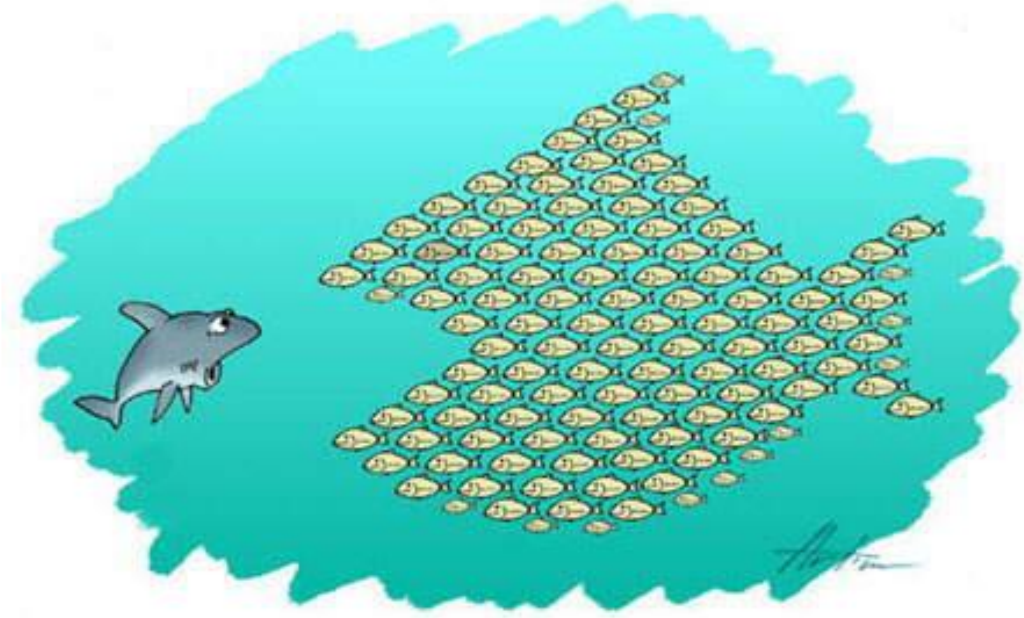
Resolving Physical Contradictions
Separation in System Level

If one of the contradictory demands is required at the Subsystem or Supersystem level, separate them using "Separation in System Level" method



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Resolving Physical Contradictions
Example: Strong Cable

- Engineering System:
  - A cable
- Physical Contradiction:
  - The cable should be made of a cast iron to be strong, BUT
  - The cable should not be made of a cast iron to be flexible
- Resolving Method:
  - Both requirements apply to the same area of space and point in time and refer to the same object => neither separation in space, nor in time, nor in relation are not applicable

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Resolving Physical Contradictions
Recommended Inventive Principles

- Principle 1 — Segmentation
  - Divide an object into independent parts
  - Make an object easy to disassemble
  - Increase the degree of fragmentation or segmentation
- Principle 5 — Merging
- Principle 12 — Equipotentiality
- Principle 33 — Homogeneity

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Example: Strong Cable
Solution

- The components of the chain are made of cast iron and are rigid but he whole chain is flexible and can be folded for storage purposes

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Resolving Physical Contradictions
Example: Bottle of Salad Dressing

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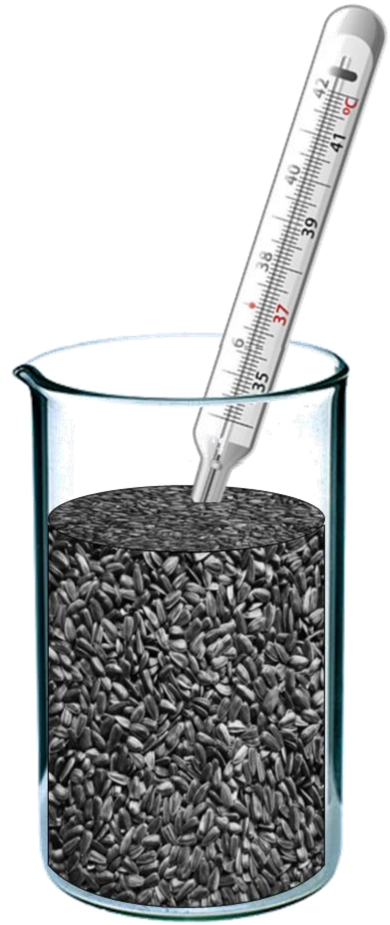
Resolving Physical Contradictions
Example : Measurement of Beetle Body Temperature



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Resolving Physical Contradictions
Example: Counting Number of Bacteria

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Resolving Physical Contradictions

Ways of Resolving Physical Contradictions:

- Separating Contradictory Demands
  - Separation in Space (key question “where?”)
  - Separation in Time (key question “when?”)
  - Separation in Relation (key question “for whom?”)
  - Separation in Direction (key question “in what direction?”)
  - Separation in System Level (no key question)
- Satisfying Contradictory Demands
- Bypass

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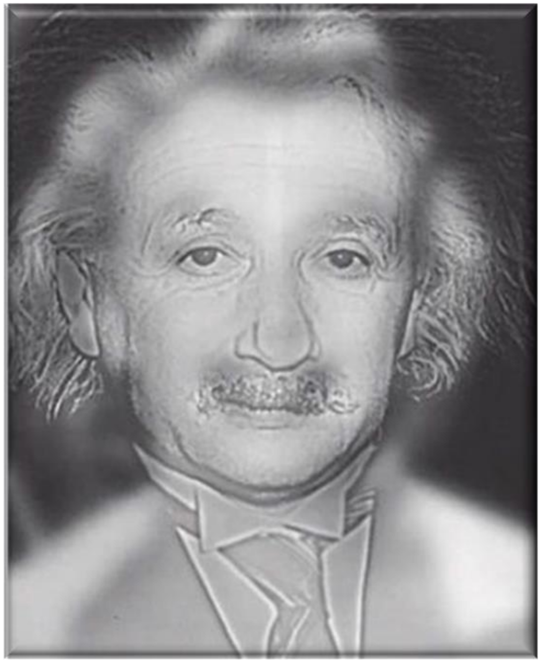
Resolving Physical Contradictions
Satisfying Contradictory Demands

If the contradiction cannot be resolved using separation, it may be possible to satisfy both demands simultaneously



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Resolving Physical Contradictions
Recommended Inventive Principles

- Principle 13 — The other way around
- Principle 28 — Mechanics substitution
- Principle 35 — Parameter changes
- Principle 36 — Phase transition
- Principle 37 — Thermal expansion
- Principle 38 — Strong oxidants
- Principle 39 — Inert atmosphere

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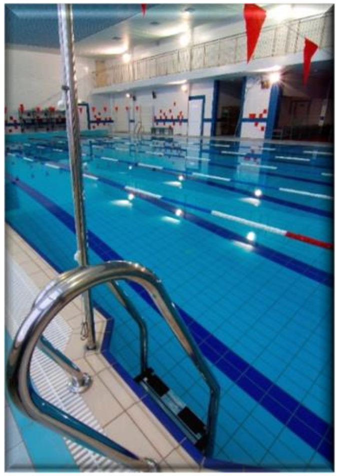
Resolving Physical Contradictions
Example: Training of long-distance swimmers



- Engineering System:
  - A swimming pool
- Physical Contradiction:
  - The swimming pool should be long to avoid frequent turns, BUT
  - The swimming pool should be short to have a compact infrastructure
- Comments:
  - Any turns are not allowed, therefore a ring-shaped swimming pool is not a solution
- Resolving Method:
  - No any types of separation are applicable. It means that we need to develop a very long but quite compact swimming pool

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Resolving Physical Contradictions
Solution

- Inventive Principle “The other way around”
  - Invert the action used to solve the problem (e.g. instead of cooling an object, heat it)
  - Make movable parts (or the external environment) fixed, and fixed parts movable
  - Turn the object (or process) “upside down”
- Solution:
  - By analogy to a treadmill, the water is moved against the swimmer. Thus the athlete can swim long distances without actually moving forward

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Resolving Physical Contradictions

Ways of Resolving Physical Contradictions:

- Separating Contradictory Demands
  - Separation in Space (key question “where?”)
  - Separation in Time (key question “when?”)
  - Separation in Relation (key question “for whom?”)
  - Separation in Direction (key question “in what direction?”)
  - Separation in System Level (no key question)
- Satisfying Contradictory Demands
- Bypass

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Resolving Physical Contradictions
Bypassing Contradictory Demands

If the contradiction cannot be resolved using separation or by satisfying both the demands, it may be possible to bypass the contradictory demands

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Resolving Physical Contradictions
Bypassing Contradictory Demands: Example

- Physical Contradiction:
  - The ship must be narrow to reduce the hydrodynamic resistance, BUT
  - It must be wide to be stable
- Comment:
  - Let us assume that neither the separation of opposite requirements nor their simultaneous satisfaction is possible. So we should try to get around the problem by radically changing the object.
- Solution:
  - A hovercraft. In motion, it does not touch water; therefore, the task of reducing hydrodynamic resistance does not arise at all

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Resolving Physical Contradictions
Algorithm for Formulating Physical Contradiction

- Formulate the problem
- Define the object that should be improved according to the problem requirements
- Define the object parameter that significantly affects the problem requirements
- Define value of this parameter that solves the problem
- Formally define an opposite value (e.g. “big” → “small”)
- Try to justify this opposite value. Typical justifications:
  - Providing some positive effect (“to provide…”, “to make…”)
  - Preventing some negative effect (“to prevent…”)
  - Current presence of this value (“because it is its natural property/state”)
- Variant 1:
  - There is the justification. It means that there are two opposite justified requirements to the same parameter of the same object – it is the Physical Contradiction
- Variant 2:
  - There is no justification. It means that you have got a solution: “To solve the problem, it is necessary to provide the defined value of the defined parameter”, or now you have the new problem: “How to provide the defined value of the defined parameter?”

Exercise

- In northern seas, buildup of ice on ships can be dangerous. Water, picked up by the wind from wave tops, freezes on exposed parts of the ship. The ice can form more rapidly than the crew is able to chop it off, and a ship can capsize under the accumulated weight of the ice.

Exercise

- Molten slag is transported from a blast furnace to a slag processing installation in ladles on railway tracks. During transport, the slag cools and a hard crust forms on its surface. To unload the slag, the crust must be broken using special equipment. Only part of the ladle contents can be unloaded, however, and the remaining slag must be disposed of in a scrap heap, which pollutes the environment. Furthermore, emptying the ladles is labor-intensive. Improving the heat insulation of the ladles does not solve the problem. Likewise, removable lids are difficult to transport and require special cranes for opening and closing.

PROBLEM SOLVING AND CONCEPT GENERATION

Concept Development- Combining

- The more diligent we have been in documenting ideas – both new and old , the more opportunities we will have to combine ideas
- It is not uncommon for 80% of the ideas that appeared to be old ideas, and within the balance 20% there might be some outrageous ideas
- It is now time to synthesize ideas to viable concepts and solutions

Remember:

1. ***Complex problems are not usually solved by individual ideas, because complex problems are often the results of many individual, interrelated problems***
2. ***<u>Rule of concept development</u>: Each concept or solution is a new problem to solve. Subsequent tasks should be easier to solve than the associated original new problem***

Concept Development- Combining

- Combine ideas that perform the same function in different ways
- Combine systems having the same functions
- Combine systems having opposite functions
- Combine system from homogeneous elements
- Combine two or more ideas that resolve different harmful functions

- As we combine ideas the concepts become stronger and more complex.
  – Abandon the concept
  – Live with the secondary task
  – Eliminate the secondary task

IMPORTANT

As concepts are developed and new subsequent tasks appear, we should reformulate it as a new problem attack them inventively using the techniques learned

Concept Development- Combining

- To combine ideas
  1. Select two ways that resolve the same sub problem in different ways
  2. Compare these ideas; each has its own advantages and disadvantages, based on how they meet the success criteria
  3. Select the idea that you want to improve and consider it the recipient of resources
  4. Consider the other idea the source of resources
  5. Identify the resources in the source idea that allow it to meet the success criteria, then attempt to find or create those resources in the recipient idea
  6. Optimally the recipient idea will consist of resources of the source and thereby meet the criteria for success

Concept Development- Evaluation

- Analyze a developed concept
  1. Analyze the degree of elimination of the disadvantage of the problem
  2. Analyze the degree of conflict resolution (contradiction elimination)
  3. Evaluate the ideality of the concept
  4. Compare the concept with directions suggested by the Laws of Evolution
  5. Evaluate concept implementation problems

Concept Development- Evaluation

- Analyze the degree of elimination of the disadvantage of the problem
  - Has the concept eliminated the disadvantage of the problem?
  - What are the new disadvantages bought by the concept?
  - If the concept has eliminated the original disadvantage but causes a new disadvantage solve this concept using the method learnt
- Analyze the degree of the conflict resolution
  - What physical contradictions has to be eliminated? Has it actually been eliminated by the solution?
    - If the conflicting requirements have not been separated , return to the problem
    - If the conflicting requirements have been separated but the concept causes a new disadvantage , state the subsequent problem

Concept Development- Evaluation

- Evaluate the ideality of the concept
  - Compare the concept with the corresponding ideal way
  - Compare the concept with the Ideal final result
  - Have you avoided introducing new substances anf fields
  - State subsequent problems to increase the degree of utilization of existing and modified resources
- Evaluate the limit of the concept
  - Formulate a problem to overcome the limitation of the concept
- Compare concepts with the directions suggested by the laws of evolution
- Evaluate concept implementation problems
  - Evaluate technical problems
  - Evaluate availability of the resources
  - Evaluate time and cost of implementation of the concept

Planning the Implementation

Planning the Implementation

1. Planning a pilot project
2. Implementation plan
3. Customer satisfaction
4. Protecting the solution

Planning a Pilot Project

1. In planning a pilot project, consider the following:
   i. What should be piloted in order for a decision to be made about implementation?
   ii. What departments and individuals must be involved in the pilot project and its evaluation?
   iii. What is it that you need to determine and/or investigate by way of a pilot project?
   iv. How close should the pilot project be to the real-life situation? Should it be:
      - a small-scale project?
      - a full-scale project?
      - a computer simulation?
   v. When and how should you test your solution under working conditions?
   vi. What failures might occur as you transition to the full implementation of your solution?

Implementation plan

2. Ask yourself the following questions:
   i. Do you have an implementation plan? In particular:
   ii. Have you prepared a project outline?
   iii. Are the milestones defined?
   iv. What are the criteria for success?
   v. Do you have a worst-case scenario?
   vi. Who is personally responsible for the implementation and how strongly is he/she motivated to succeed? In particular:
      – Whom does he/she report to?
      – Is the implementation his/her only responsibility, or is it just one of many?
      – How will the implementing person (or team) be evaluated? How will this affect their performance?
      – What will be the reward (or penalty, depending on the results of implementation)? Will the reward/penalty system be individual- or team-based?

Implementation plan (cont)

vii. Will one or more existing units be responsible for implementation, or should a new unit be organized specifically for this purpose? In particular:
  - How large should the unit be?
  - Can you influence this unit?
  - How might you motivate this unit to be successful in the implementation?

viii. Does anybody involved with the implementation have a conflict of interest? If yes, what should be done to resolve or eliminate this conflict?

ix. Are all the technical resources required for testing available?

x. Are you ready to address new (secondary) problems that might arise during implementation?

xi. Are all the financial resources required for complete implementation available? What if new investments are required?

xii. What if the implementation takes longer than expected?

Customer satisfaction

3. Think about the following issues:
   i. Who is the customer?
   ii. What will the ultimate result of your solution be?
   iii. What does the total solution consist of? Is it enough to ensure effective performance? Can it be integrated with existing operations?
   iv. Is your solution complete? Will the recipients of the solution have everything they need to use your solution on an ongoing basis?
   v. Do you have a feedback mechanism that allows for the estimation of results for the purpose of making further improvements?
   vi. Do you have a mechanism for detecting dissatisfied customers and providing them with complete satisfaction?

Protecting the solution

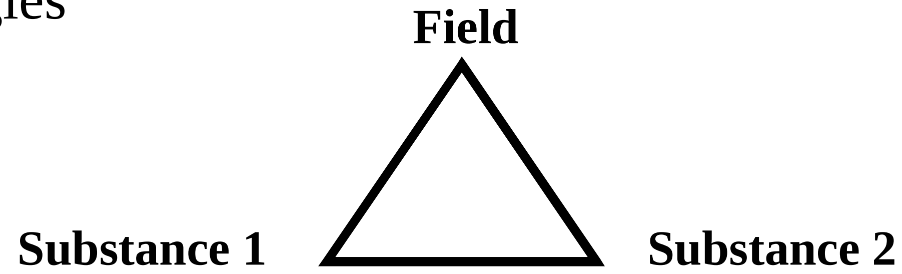
4. Does it make sense to obtain a patent or other protection for your solution (keep it as a trade secret, for instance)?

INTRODUCTION TO SU- FIELD MODELING

S-F Modeling

Substance Field (S-F) Modeling

- The minimal model of functioning technological systems includes two substances interacting through a field or force (energy)
- The system can be modeled by a triangle relating the substance and the field
- Complex systems can be modeled by multiple S-F triangles



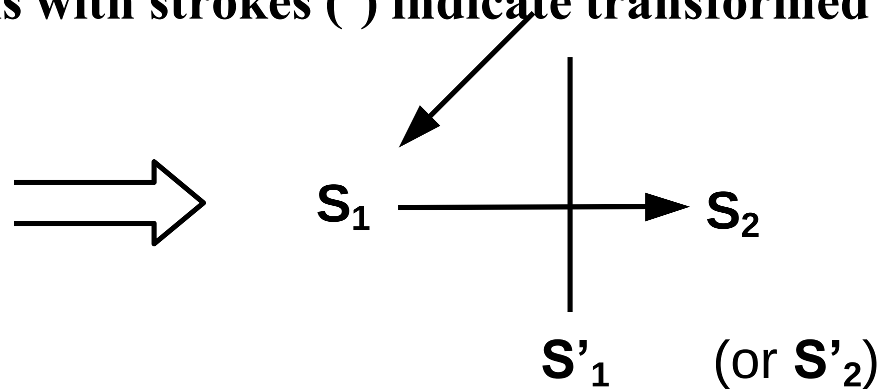
how to protect a hydrofoil moving at a high speed from hydraulic cavitations, which results from collapsing air bubbles which destroy the metal surface of the foil? And the second problem:

how to prevent orange plantations from being eaten by monkeys if installing fences around the plantations would be too expensive?

Is there any similarity in the two problems?

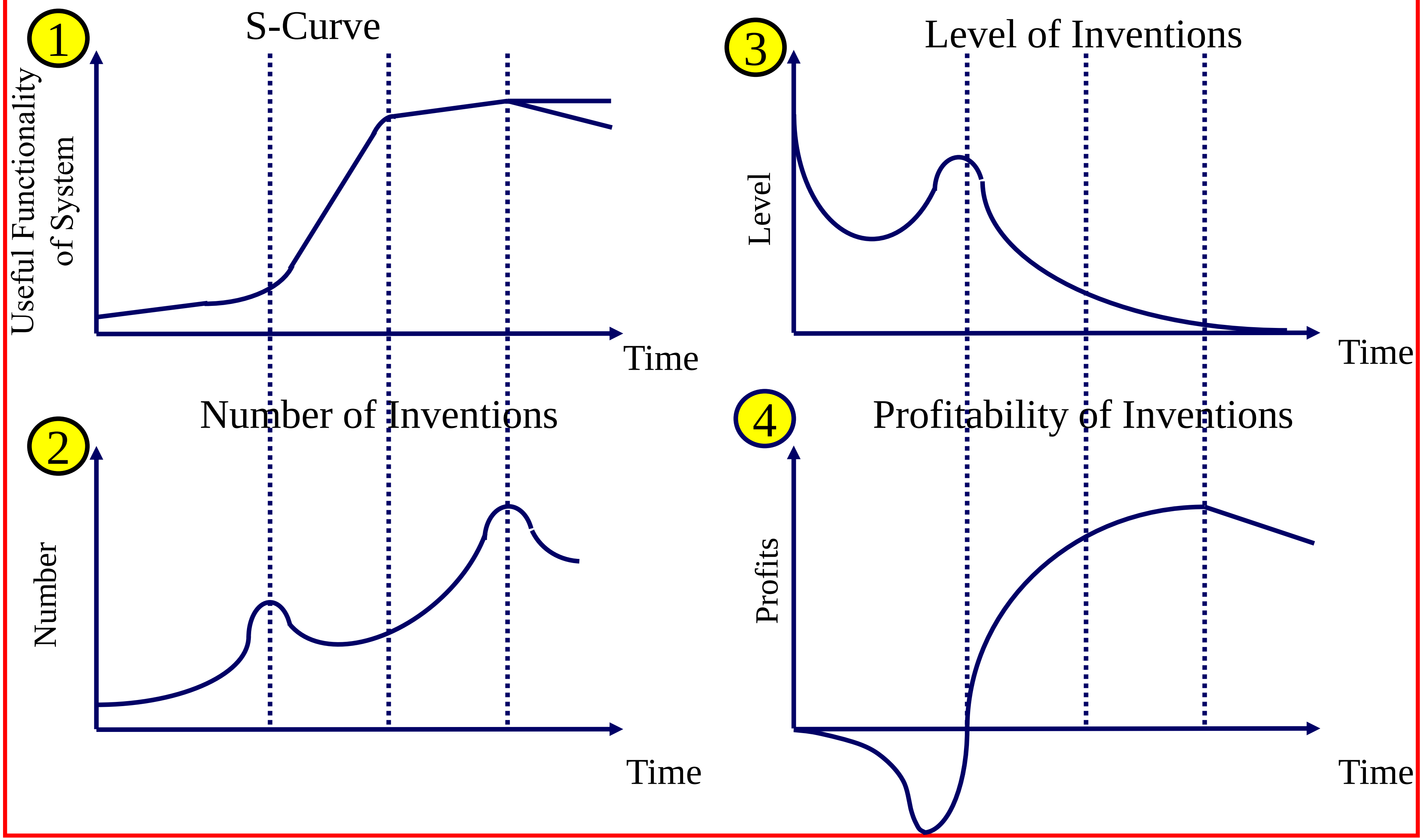
Destruction of SFM

- <u>**STANDARD 1-2-2.**</u> **If there are a useful and a harmful effects between two substances, and there is no need to maintain direct contact between the substances, and it is forbidden or inconvenient to use foreign substances, the problem can be solved by introducing a third substance between the two, which is a modification of the first or the second substance.**
- **The symbols with strokes (‘) indicate transformed substance.**

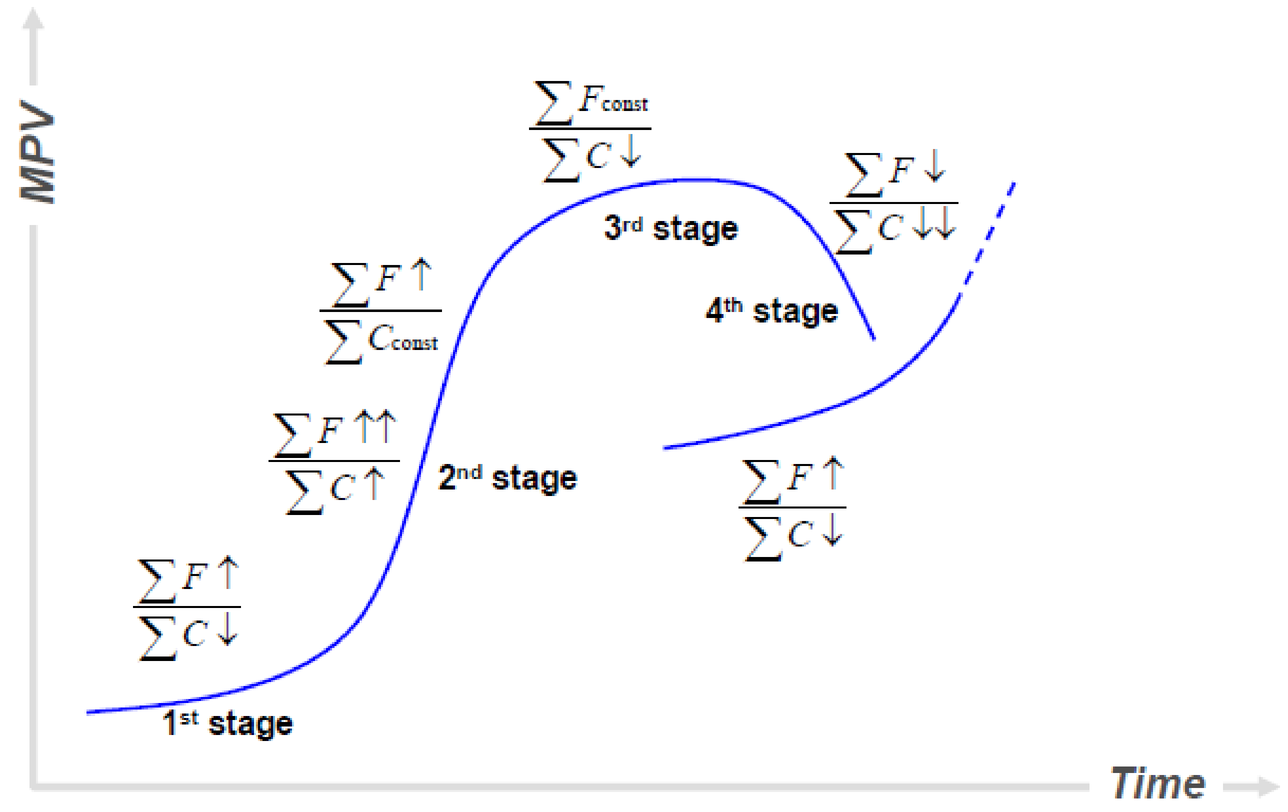


INTRODUCTION OF S CURVE ANALYSIS

S-Curve Analysis

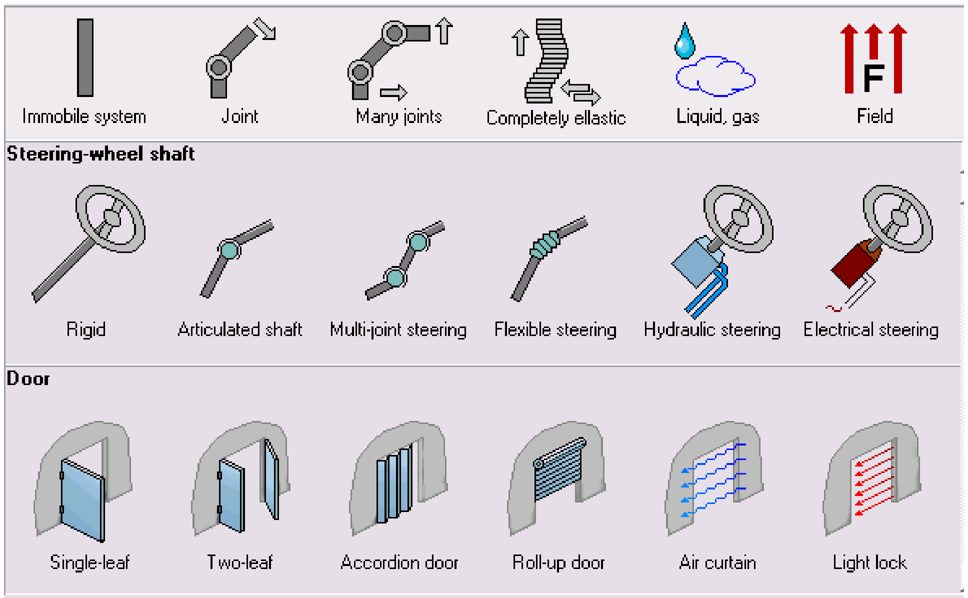


Summary of action depending on position



INTRODUCTION TO LAWS OF EVOLUTION

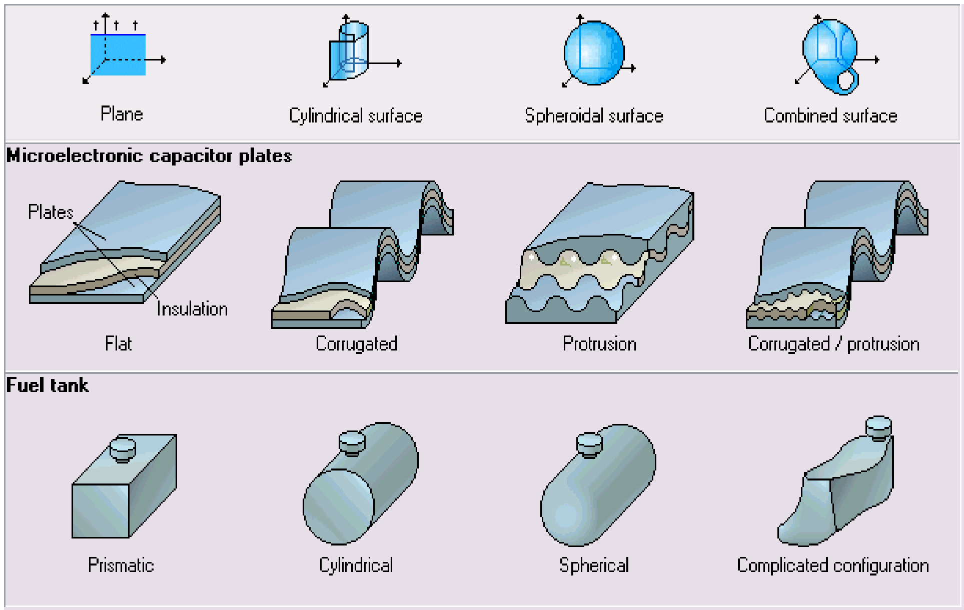
Dynamization



Evolution Stage	Reasons for Jumps
Immobile to Jointed	-fold to make more compact -maneuverability -increase positional flexibility -mechanical 2-way switching -solving physical contradiction (e.g. wide and narrow) -variable deflector (e.g. flap on aircraft wing) -compound properties (e.g. stiff and flexible parts) -damage protection
Jointed to Multiple Jointed	- more compact folding -positional flexibility -multi-way switching -compound properties
Multiple Jointed to Fully Flexible	-positional flexibility -smooth deflection -compact installation -continuous variability -impact load damage resistance
Fully Flexible to Fluid/Pneumatic	-positional flexibility -improve power/weight ratio -improve strength/wt -increase reliability -increase convenience
Fluid/Pneumatic to Field	-increase reliability -increase operation flexibility -increase efficiency -increase control precision -increase power density -increase ability to change system characteristics

Steering systems, power transmission means, window blinds, doors/security systems, medical stent, ruler/measuring devices, chair, desk-lamps, sound recording (vinyl to tape to optical).

Geometric Evolution Volumetric



Evolution Stage	Reasons for Jumps
Planar to 2D	- improve load distribution - improve flow distribution - increase surface area - change aspect ratio - create ability to identify/change component orientation - add a new useful function
2D to Axi-symmetric	- improve load distribution - improve flow distribution - improve strength properties - improve moment of inertia - improve location for two joining parts - increase surface area - add new function
Axi-symmetric to Fully 3D	- improve compatibility with 'real world' effects-improve structural strength - improve aesthetics - improve ergonomics - improve surface area - add new function

Examples

CAD systems, fuel tanks/containers, aerodynamic structures, watering can, furniture, car headlights, ergonomic keyboards, hi-fi speakers.

QUESTIONS?
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"TRIZ is a theory for thinking but not instead of thinking".

G. Altshuller