

TRIZ Forty Inventive Principles

Support material for *The Mechanical Design Process*, 6th edition, David G. Ullman, 2017

1. Segmentation

- a. Divide an object into independent parts
- b. Make an object sectional
- c. Increase a degree of an object's segmentation

Examples:

1. Sectional furniture, modular computer components, folding wooden ruler
2. Garden hoses can be joined together to form any length needed

2. Extraction

- a. Extract (remove or separate) a "disturbing" part or property, from an object, or
- b. Extract the only necessary part or property

Example:

1. To scare birds from the airport, reproduce the sound known to excite birds using a tape recorder.

3. Local quality

- a. Transition from a homogeneous structure of an object or outside environment (outside action) to a heterogeneous structure
- b. Have different parts of the object carry out different functions
- c. Place each part of the object under conditions most favorable for its operation

Examples:

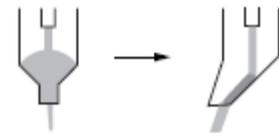
1. To combat dust in coal mines, a fine mist of water in a conical form is applied to working parts of the drilling and loading machinery. The smaller the droplets, the greater an effect in combating dust, but fine mist hinders the work. The solution is to develop a layer of coarse mist around the cone of fine mist.
2. A pencil and an eraser in one unit

4. Asymmetry

- a. Replace a symmetrical form with an asymmetrical form of the object
- b. If an object is already asymmetrical, increase the degree of asymmetry

Examples:

1. One side of the tire is stronger than the other to withstand impact with the curb
2. While discharging wet sand through a symmetrical funnel the sand forms an arch above the opening, causing irregular flow. A funnel of asymmetrical shape completely eliminates the arching effect.



5. Combining

- a. Combine in space homogeneous objects or objects destined for contiguous (adjacent) operations
- b. Combine in time homogeneous or contiguous operations

Example:

1. The working element of a rotary excavator has special steam nozzles to defrost and soften the frozen ground in a single step

6. Universality

- a. Have the object perform multiple functions, thereby eliminating the need for some other objects

Examples:

- 1. Sofa which converts from a sofa in the daytime to a bed at night
- 2. Minivan seat which adjusts to accommodate seating, sleeping, or carrying cargo

7. Nesting

- a. Contain the object inside another which in turn is placed inside a third object
- b. An object passes through a cavity of another object

Examples:

- 1. Telescoping antenna
- 2. Stacking chairs (on top of each other for storage)
- 3. Mechanical pencil with lead stored inside

8. Counterweight

- a. Compensate for the object's weight by joining with another object that has a lifting force
- b. Compensate for the weight of an object by interaction with an environment providing aerodynamic or hydrodynamic forces

Examples:

- 1. Boat with hydrofoils
- 2. A rear wing in racing cars to increase the pressure from the car to the ground

9. Prior counter-action

- a. If it is necessary to carry out some action, consider a counter-action in advance
- b. If by the problem statement an object has to have a tension, provide anti-tension in advance

Examples:

- 1. Reinforced concrete column or floor
- 2. Reinforced shaft—in order to make a shaft stronger the shaft made out of several pipes that have been previously twisted to a calculated angle

10. Prior action

- a. Carry out the required action in advance in full, or at least in part
- b. Arrange objects so they can go into action without time loss waiting for action (and from the most convenient position)

Examples:

- 1. Utility knife blade made with a groove allowing the dull part of the blade to be broken off, restoring sharpness
- 2. Rubber cement in a bottle is difficult to apply neatly and uniformly. Instead, it is formed into a tape so that the proper amount can be more easily applied.

11. Cushion in advance

- a. Compensate for the relatively low reliability of an object by countermeasures taken in advance

Example:

- 1. To prevent shoplifting the owner of the store attaches a special tag containing a magnetized plate. In order for the customer to carry out the merchandise, the plate is demagnetized by the cashier.

12. Equipotentiality

- a. Change the condition of work so that an object need not be raised or lowered

Example:

- 1. Automobile engine oil is changed by workers in a pit (so that expensive lifting equipment is not needed)

13. Inversion

- a. Instead of an action dictated by the specifications of the problem, implement an opposite action
- b. Make a moving part of the object or the outside environment immovable and the non-moving part moveable
- c. Turning the object upside down

Example:

- 1. Abrasively cleaning parts by vibrating the parts instead of the abrasive

14. Spheroidality

- a. Replace linear parts or flat surfaces with curved ones, cubical shapes with spherical shapes
- b. Use rollers, balls, spirals
- c. Replace a linear motion with rotating movement, utilize a centrifugal force

Example:

- 1. Computer mouse utilizes ball construction to transfer linear two axis motion into vector motion

15. Dynamicity

- a. Make characteristics of an object, or outside environment automatically adjust for optimal performance at each stage of operation
- b. Divide an object into elements able to change position relative to each other
- c. If an object is immovable, make it movable or interchangeable

Examples:

- 1. A flashlight with a flexible gooseneck between the body and the lamp head
- 2. A transport vessel with the body of a cylindrical shape. To reduce the draft of a vessel under full load the body, comprised of two hinged half-cylindrical parts that can be opened.

16. Partial or overdone action

- a. If it is difficult to obtain 100% of a desired effect, achieve somewhat more or less to greatly simplify the problem

Examples:

- 1. A cylinder is painted by dipping into paint, but contains more paint than desired. Excess of paint is then removed by rapidly rotating the cylinder
- 2. To obtain uniform discharge of a metallic powder from a bin, the hopper has a special internal funnel which is continually overfilled to provide nearly constant pressure

17. Moving to a new dimension

- a. Remove problems in moving an object in a line by two-dimensional movement (along a plane). Similarly, problems in moving an object in a plane are removed if the object can be changed to allow three dimensional space.
- b. Use a multilayer assembly of objects instead of a single layer
- c. Incline the object or turning it “on its side”
- d. Project images onto neighboring areas or onto the reverse side of the object

Example:

- 1. A greenhouse which has a concave reflector on the northern part of the house to improve illumination of that part of the house by reflecting the sun light during the day

18. Mechanical vibration

- a. Set an object into oscillation
- b. If oscillation exists, increase its frequency, even as far as ultrasonic
- c. Use the frequency of resonance
- d. Instead of mechanical vibrations, use piezovibrators
- e. Use ultrasonic vibrations in conjunction with an electromagnetic field

Examples:

- 1. To remove a cast from the body without skin injury, a conventional hand saw was replaced with a vibrating knife
- 2. Vibrate a casting mold while it is being filled to improve flow and structural properties

19. Periodic action

- a. Replace a continuous action with a periodic one, or impulse
- b. If an action is already periodic, change its frequency
- c. Use pauses between impulses to provide additional action

Examples:

- 1. An impact wrench loosens corroded nuts using impulses rather than a continuous force
- 2. A warning lamp flashes so that it is even more noticeable than if continuously lit

20. Continuity of useful action

- a. Carry out an action without a break—all parts of an object should be constantly operating at full capacity
- b. Remove an idle and intermediate motions

Example:

- 1. A drill with cutting edges which permit cutting process in forward and reverse directions

21. Rushing through

- a. Perform harmful or hazardous operations at very high speed

Example:

- 1. A cutter for thin wall plastic tubes prevents tube deformation during cutting by running at a very high speed (cuts before the tube has a chance to deform)

22. Convert harm into benefit

- a.** Utilize a harmful factor or harmful effect of an environment to obtain a positive effect
- b.** Remove a harmful factor by adding it with another harmful factor
- c.** Increase the amount of harmful action until it ceases to be harmful

Examples:

- 1.** Sand or gravel freezes solid when transported through cold climates. Over-freezing (using liquid nitrogen) embrittles the ice, permitting pouring.
- 2.** When using high frequency current to heat metal, only the outer layer was heated. This negative effect was later used for surface heat treating.

23. Feedback

- a.** Introduce feedback
- b.** If feedback already exists, reverse it

Examples:

- 1.** Water pressure from a well is maintained by sensing output pressure and turning on a pump if pressure is too low
- 2.** Ice and water are measured separately but must be combined to an exact total weight. Because it is difficult to precisely dispense the ice, it is measured first and the weight is fed to the water control, which precisely dispenses the needed amount.
- 3.** Noise canceling devices sample noise signals, phase shift them and feed them back to cancel the effect of the noise source

24. Mediator

- a.** Use an intermediary object to transfer or carry out an action
- b.** Temporarily connect an object to another one that is easy to remove

Example:

- 1.** To reduce energy loss when applying current to a liquid metal, cooled electrodes and intermediate liquid metal with a lower melting temperature are used

25. Self-service

- a.** Make the object service itself and carry out supplementary and repair operations
- b.** Make use out of waste of material and energy

Examples:

- 1.** To distribute an abrasive material evenly on the face of crushing rollers and to prevent the feeder from wearing, its surface is made out of the same abrasive material
- 2.** In an electric welding gun, the rod is advanced by a special device. To simplify the system, the rod is advanced by a solenoid controlled by the welding current.

26. Copying

- a.** Use simple and inexpensive copy instead of an object which is complex, expensive, fragile, or inconvenient to operate
- b.** Replace an object or a system of objects by their optical copies.
- c.** If visible optical copies are used, replace them with infrared or ultraviolet copies

Example:

- 1.** The height of tall objects can be determined by measuring their shadows

- 27.** An inexpensive short-life object instead of an expensive durable one
- a.** Replace an expensive object by a collection of inexpensive ones, compromising other properties (longevity, for instance)
- Examples:*
- 1.** Disposable diapers
 - 2.** A single usage mousetrap consisting of a plastic tube with bait. A mouse enters the trap through a cone-shaped opening; the walls of the opening are angled and do not allow the mouse to get out.
- 28.** Replacement of a mechanical system
- a.** Replace a mechanical system by an optical, acoustical, or odor system
 - b.** Use an electrical, magnetic or electromagnetic field for interaction with the object
 - c.** Replace fields:
 - 1.** Stationary fields with moving fields
 - 2.** Fixed to those changing in time
 - 3.** From random to structured
 - d.** Use a field in conjunction with ferromagnetic particles
- Example:*
- 1.** To increase a bond of metal coating to a thermoplastic material the process is carried out inside an electromagnetic field to apply force to the metal
- 29.** Use a pneumatic or hydraulic construction
- a.** Replace solid parts of an object by gas or liquid—these parts can use air or water for inflation or use air or hydrostatic cushions
- Examples:*
- 1.** To increase the draft of an industrial chimney a spiral pipe with nozzles was installed. When the air starts flowing through the nozzles, it creates an air-like wall, reducing drag.
 - 2.** For shipping fragile products air bubble envelopes or foam-like materials are used
- 30.** Flexible film or thin membranes
- a.** Replace customary constructions with flexible membranes and thin film
 - b.** Isolate an object from outside environment with thin film or fine membranes
- Example:*
- 1.** To prevent the loss of water evaporating from the leaves of plants, polyethylene spray was applied. After a while the polyethylene hardened and plant growth much improved because the polyethylene film passes oxygen better than water vapor.
- 31.** Use of porous material
- a.** Make an object porous or use additional porous elements (inserts, covers, etc.)
 - b.** If an object is already porous fill the pores in advance with some substance
- Example:*
- 1.** To avoid pumping coolant to a machine, some of the parts of the machine are filled with porous material (porous powdered steel) soaked in coolant liquid which evaporates when the machine is working, providing short-term uniform cooling

32. Changing the color

- a. Change the color of an object or its surroundings
- b. Change the degree of translucency of an object or surroundings
- c. Use colored additives to observe objects or processes which are difficult to see
- d. If such additives are already used, employ luminescent traces or tracer elements

Examples:

- 1. A transparent bandage enabling a wound to be inspected without the dressing being removed
- 2. In steel mills a water curtain was designed to protect workers from overheating. But this curtain only protects from infrared rays, so the bright light from the melted steel can easily get through the curtain. A coloring was added to the water to create a filter effect while remaining transparent.

33. Homogeneity

- a. Make objects interacting with a primary object out of the same material or material that is close to it in behavior

Example:

- 1. The surface of a feeder for abrasive grain is made of the same material that runs through the feeder—allowing it to have a continuous restoration of the surface without being worn out

34. Rejecting and regenerating parts

- a. After it has completed its function or become useless reject or modify (e.g., discard, dissolve, or evaporate) an element of an object
- b. Restore directly any used up parts of an object

Examples:

- 1. Bullet casings are ejected after the gun fires
- 2. Rocket boosters separate after serving their function

35. Transformation of physical and chemical states of an object

- a. Change an aggregate state of an object, concentration of density, the degree of flexibility, the temperature

Example:

- 1. In a system for brittle friable materials, the surface of the spiral feed screw was made from an elastic material with two spiral springs. In order to control the process the pitch of the screw could be changed remotely.

36. Phase transition

- a. Implement an effect developed during the phase transition of a substance. For instance, during the change of volume, liberation or absorption of heat.

Example:

- 1. To control the expansion of ribbed pipes, they are filled with water and cooled to a freezing temperature

37. Thermal expansion

- a.** Use expansion or contraction of material by heat
- b.** Use various materials with different coefficients of heat expansion

Example:

- 1.** To control the opening of roof windows in a greenhouse, bimetallic plates are connected to the windows. With a change of temperature, the plates bend and make the window open or close.

38. Use strong oxidizers

- a.** Replace normal air with enriched air
- b.** Replace enriched air with oxygen
- c.** Treat in air or in oxygen with ionizing radiation
- d.** Use ionized oxygen

Example:

- 1.** To obtain more heat from a torch, oxygen is fed to the torch instead of atmospheric air

39. Inert environment

- a.** Replace the normal environment with an inert one
- b.** Carry out the process in a vacuum

Example:

- 1.** To prevent cotton from catching fire in a warehouse, it is treated with inert gas during transport to the storage area

40. Composite materials

- a.** Replace a homogeneous material with a composite one

Example:

- 1.** Military aircraft wings are made of composites of plastics and carbon fibers for high strength and low weight

SOURCE

Creativity as an Exact Science, by G. S. Altschuller, 1984, Gordon and Breach Science Publishers, NY.