

40 Principles for Innovative Problem Solving

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Business Examples: The TRIZ Journal, September 1999

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Food Technology Examples: The TRIZ Journal, October 2001

Software Development Examples: The TRIZ Journal, September and November 2001

Microelectronics Examples: The TRIZ Journal, August 2002

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Principle 1. Segmentation. Fragmentation. Transition to micro-level. Divide an object or system into independent parts. Make an object easy to disassemble. Increase the degree of fragmentation or segmentation.

Use blinds or mini-blinds instead of continuous shades.

Divide a large truck into a tractor and trailer.

Use Java applets instead of a single large program.

Stone washing is one of the technologies used to give denim needed features and appearance. Stones are, however, rather crude tools, and clumsy machinery is needed to handle them. A nice solution is to use enzymes instead of stones to get the same result. Enzymes are not literally small stones, but the concept of using molecules instead of large objects comes from the principles of segmentation.

The segmentation principle has many applications in business. The segmentation of the market is a common practice and a commonly used term. Most big corporations have segmented themselves into business units or profit centers. A corporation should be small, to be flexible, AND big, to have enough resources for production and marketing. To get small and big at the same time, a huge company is divided to subsidiaries, profit centers, or other units, working relatively independently. The ABB Company and the Gore Corporation are exemplary—they create a new organization whenever an existing part of the company exceeds 150 people.

For the last 30 years the use of teams has been one of the persistent themes in the workplace, because small teams are flexible, and can make decisions quickly.

A large job can be broken into many smaller jobs (called a “work breakdown structure” in project management). The JIT (Just-in-time or Kanban) system uses the concept of segmentation to an extreme—it replaces the idea of mass production with the idea that the most efficient production system can produce a single unit just as easily as multiple units.

Entertainment examples: serialized novels and TV movies.

Principle 2. Separation. Separate the only necessary part (or property), or an interfering part or property from an object or system.

We need light, not lighting devices. Use a fiber optic to take light to the place it is needed, and leave the source of light and control outside (such as getting light at the tip of a surgical instrument.)

We don't need a vacuum cleaner as such, but cleaning capacity. A central vacuum cleaning system leaves only nozzles and a piece of tubing in the apartment. Noisy and dirty parts are removed to the place where they don't disturb inhabitants.

The wired electric lawnmower can work quite well if the lawn is not big. The production of energy is removed from the lawn.

Put a noisy compressor outside the building, and pipe the compressed air to the place that it is needed—most medical and dental offices are built this way.

Franchising separates the ownership of a local business such as a restaurant or a printing shop from the development of the concept and the systems that make it successful.

The ASP (Application System Provider) is a new concept—your company doesn't own its own software, but rents it as needed from a "Provider." All outsourcing, including staffing services as well as production and information management services could be considered examples of this principle.

Principle 3. Local quality ("Qualities" are the properties of the object or system.) Change a system or object's structure from uniform to non-uniform; change an external environment (or external influence) from uniform to non-uniform. Make each part of an object or system function in conditions most suitable for its operation. Make each part of an object fulfill a different and useful function.

Quenching and other treatments of the surface layer of metal components make the surface properties different from the bulk properties of the material.

Use a different wrench for every nut, because fixed size wrenches are much stronger than adjustable wrenches.

Specialized compartments in a lunchbox for each type of food keep hot things hot, cold things cold, and make it safe and economical for workers and schoolchildren to carry their lunches with them.

In business the segmentation of the market illustrates the local quality principle, too. Segmentation is used to divide the market into small markets with specific attributes, then local quality is used to treat each of those markets appropriately. The Whirlpool Company has hired marketing people who speak 18 different languages in India, to tailor its approach to the automatic washing machine market to the cultural preferences of each group.

Local quality applies to people, too. Some are most effective working on their own, and others are most effective in teams. Deep professional specialization is needed for certain skills, and a broad liberal arts background is needed for other situations.

Principle 4. Symmetry change. Change the shape of an object or system from symmetrical to asymmetrical. If an object is asymmetrical, increase its degree of asymmetry.

Asymmetric paddles mix more effectively than symmetrical ones (both for concrete and for cake batter!).

Asymmetric scissors are easier on the hand than symmetric ones.

Mass customization is a business strategy that corresponds to asymmetry—the product or service or policies of a business are specifically designed for each customer, and don't need to be the same as those provided to other customers. (See articles by D. Mann and E. Domb, ETRIA, Nov. 2001 and TRIZ Journal, December 1999.)

Principle 5. Merging. Bring closer together (or merge) identical or similar objects; assemble identical or similar parts to perform parallel operations. Make operations contiguous or parallel; bring them together in time.

Integration in microelectronics, putting many circuit elements on the same chip.

Telephone and computer networks.

Paper sheets constitute a book, books a library.

Fragile and weak components, such as glass plates can be made stronger without increasing weight by combining them to packages.

In the section on segmentation (principle 1) we discussed big corporations that are dividing themselves to get small at the same time. Small companies or individual entrepreneurs have often the opposite problem: how to get big while remaining small. Networking is perhaps the most popular solution. There are others: chains of companies, franchising schemes, and conventional mergers. Segmentation and merging principles are often most effective if used together. Organizations are segmented, and then the parts merge.

Principle 6. Multi-functionality or universality. Make a part of an object or system perform multiple functions; eliminate the need for other parts. The number of parts and operations are decreased, and useful features and functions retained.

ABB has developed an electric generator with high voltage. A conventional transformer is not needed, since the generator can directly feed the electric network.

In some new car designs the flywheel, alternator, starter and some other parts are combined into a single component.

Use a single adjustable wrench for all nuts.

People use the universality principle also. Cross-functional training makes people much less susceptible to layoffs, since they have multiple skills instead of one skill. Compare this with the local quality principle (3)

Principle 7. "Nested doll". Place one object inside another; place each object, in turn, inside the other. Make one part pass through a cavity in the other. The name of this principle comes from the Russian folk art dolls, in which a series (usually six or seven) of wooden dolls are nested, one inside the other.

The double hull in oil tankers.

Telescope structures (umbrella handles, radio antennas, pointers.)

Business analogies: a boutique store inside a big market

File structures in the Windows computer operating system (Chapter 10 is a file in the NewTRIZ Book file, which is a file in the My Documents file, ...)

Principle 8. Weight compensation. To compensate for the weight of an object or system, merge it with other objects that provide lift. To compensate for the weight of an object, make it interact with the environment (e. g. use aerodynamic, hydrodynamic, buoyancy and other forces).

Air tanks in submarine vessels.

Lifting bodies (the shape of the fuselage acts like a wing and generates lift. Used in both aircraft and ship design.)

Banners and signs cut so that the wind lifts them for display.

Business analogies: Compensation for the heavy organization pyramid with project organization, process organization, temporary organization and other less hierarchical systems “lift” the heavy structure.

Principle 9. Preliminary counteraction. If it will be necessary to do an action with both harmful and useful effects, this action should be replaced with anti-actions (counteractions) to control the harmful effects. Create stresses in an object or system that will oppose known undesirable working stresses later on.

Use an electric heater to pre-heat the car engine before starting in the winter in Northern regions. Damage to the engine from running with frozen oil is prevented, fuel is saved and air pollution decreased.

Pre-tension rebar before pouring concrete for stronger structures.

Changes and innovations meet usually resistance in the organization. Get the affected people involved so that they can participate in the planning of changes, and don't feel threatened.

Principle 10. Preliminary action. Perform, before it is needed, the required change of an object or system (either fully or partially). Pre-arrange objects such that they can come into action from the most convenient place and without losing time for their delivery.

Preliminary perforated packaging is easy to open.

Pre-cut parts for the building of wooden houses save work at the construction site.

Do market research, study possible futures, building reserves for changes.

Prepare solutions to problems customers don't speak of today, but may speak of tomorrow: environmental impact, ethical considerations, community impact.

Principle 11. Beforehand compensation. Prepare emergency means beforehand to compensate for the relatively low reliability of an object or system.

Well-known technological examples are airbags in cars and over-pressure or explosion valves in boilers.

Non-technical examples are posting instructions for possible emergency situations: fires, the use of narcotics among personnel, environment problems, and preparation of equipment (first aid and rescue kits, fire extinguishers) where they may be needed.

The “FAQ” (frequently asked questions) sections of many web sites are examples of principle 11—commonly, the user is told how to help herself to solve problems that are known to exist in the system.

Principle 12. Equipotentiality. In a potential field, limit position changes (e.g. change operating conditions to eliminate the need to raise or lower objects in a gravity field).

The flat factory. High shelving is not used in production.

Use spring systems to lift sheets of wood to the right height, so workers can slide them into the machine for the next step in the process. The Bishamon Company makes these devices—when sold as productivity tools, they were a moderate success. When advertised as tools to prevent workers’ back injuries, sales increased dramatically!

Use grounding straps to bring objects to equal electrical potential, to prevent harm from static electricity.

A business analogy may be a transition to a flatter organization with fewer hierarchical layers. One step in team formation is to bring all team members to the same level—eliminate hierarchical behaviors.

Principle 13. "The 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'.

Sometimes this principle is applied very literally—turning machines “up-side down” has solved many industrial problems. One core principle of effective design for manufacturing and assembly is to let gravity be your friend—always position parts so that they will fall naturally into the desired place.

Business examples: slow food instead of fast food, instead of the increased traveling working at home via Internet. Customers find their own answers in the consultant’s database, instead of having the consultant find the answer for them.

Television and radio bring church services to people at home, instead of people going to the church.

Principle 14. Curvature increase. Instead of using rectilinear parts, surfaces, or forms, use curvilinear ones; move from flat surfaces to spherical ones; from cube or parallelepiped shapes to ball-shaped structures. Use rollers, balls, spirals, or domes. Go from linear to rotary motion. Use centrifugal forces.

The filament in incandescent lamps was initially straight. Efficiency improved when it was coiled. Photography was first done with flat plates of glass coated with sensitive emulsion. Cameras became portable when rolls of film were developed. The transition from flat surfaces to curved ones can be easily seen in cars and telephones. A mowing machine for agriculture started with a saw-like, reciprocating edge. New machines have rotating blades, similar to those in lawnmowers.

Curvilinear, corrugated, forms often improve strength without increasing weight. Rotary motion frequently makes the equipment simpler. This was the goal of the Wankel engine.

The principle of curvature increase is often paired with principle 4: asymmetry. Components can be improved by making them or more symmetric or more asymmetric. Curvature increase may increase or decrease symmetry.

Non-technical analogies: increasing circulation of information benefits organizational function. Curved walls and streets make neighborhoods visually identifiable (both in cities and inside large office buildings and schools.)

Principle 15. Dynamic parts. Allow (or design) the characteristics of an object, external environment, process or system to change to be optimal or to find an optimal operating condition. Divide an object or system into parts capable of movement relative to each other. If an object (or process or system) is rigid or inflexible, make it movable or adaptive.

Some steps of increasing dynamics:

Rigid, immobile system

One hinge
 Many hinges
 Elastic system
 A field instead of a physical object or system

A lamp has been made more controllable introducing hinges. The penalty has been an increasing number of parts. The solution has been further improved by transition to elastic components. The single elastic component has many micro-level parts, very many very small hinges. Here the segmentation principle (1) helps the system to get more dynamic. Generally, if the improvement by one principle causes new difficulties, involve a different principle to solve the new problem.

Stiff and immovable structures are often replaced by more dynamic ones: flexible printed circuits and accumulator batteries in electronics, flexible and self-breaking light poles on the roads, wings that change form in airplanes (through the use of flaps and slats on fixed wing aircraft, and through motion of the wings on fighter aircraft) and other dynamic structures.

A first step to make a building safe for earthquakes was to make it more rigid: thicker walls, for example. Later, to avoid impractical heavy structures certain dynamics have been added: the building has bearings and shock absorbers allowing it move a little. Strength is increased without extra weight. The car has gone through similar evolution: first safety belts (passenger fixed more stiffly), then a dynamic part, the air bag, was added.

In business flexibility--the capability to make changes when the environment changes--is often the difference between success and failure. Organizations are also evolving from stiff and unchanging structures to flexible ones. Ways to increase flexibility are segmentation (principle 1), flatter organizations (see principle 12), preparing changes before encountering a problem (principles 9-11), discarding and recovering (principle 34), and others.

Schools, too, have used the principle of dynamics as part of their improvement strategy. In many schools, students are no longer assigned to a fixed grade, in which all 8-year olds do third grade studies together. Rather, the curriculum is flexible. The author's nephew recently was doing fifth grade arithmetic, third grade language studies, and a personal project to learn geography, all on the same day, in a program that was based on his abilities and interests.

Principle 16. Partial or excessive actions. If 100 percent of a goal is hard to achieve using a given solution method then, by using 'slightly less' or 'slightly more' of the same method, the problem may be considerably easier to solve.

A classical example is dipping a brush in paint, to acquire excess paint, then letting the excess drip off. Similarly, attach a stencil to a surface to be painted, then paint the whole thing. When the stencil is removed, the goal will be achieved, and the stencil will take the excess paint with it.

Pre-perforated packages are easy to open. (Cut a little bit, don't cut the whole thing!)

Preparing sketches and concepts helps many writers to get finished result more quickly.

If marketing cannot reach all possible customers, a solution may to select the subgroup with the highest density of prospective buyers and concentrate efforts on them. Another solution is an excessive action: Broadcast advertising will reach any people who are not potential buyers, but the target audience will be included in the group that is reached.

Principle 17. Dimensionality change. Move an object or system in two- or three-dimensional space. Use a multi-story arrangement of objects instead of a single-story arrangement. Tilt or re-orient the object, lay it on its side. Use 'another side' of a given area.

In conventional gardening, plants are placed in rows, that is, "one-dimensionally". Square foot gardening is the method developed for small gardens. Plants are placed in square blocks (a 4 foot block subdivided into 16 one foot squares); that is, "two-dimensionally". They are placed much closer than in large-scale agriculture. The yield is higher and weeds almost non-existent because of the close spacing.

Use of underground tunnels and buildings is increasing. At the same time there are more and more high buildings, multilevel highways and overpasses. A multi-story city is actually evolving.

Sometimes the additional dimension is invisible to the customer. Disney World in Florida in the US pioneered the multi-dimensional concept now used in many amusement parks. A network of tunnels, workshops, dressing rooms, storerooms, and staff centers runs under the park. A character is never seen in part of the park that doesn't match his or her role—instead, the worker vanishes from one area, and uses the underground system to travel to the new area, or to rest, or remove or replace parts of a costume. This preserves the illusion of the character for the visitors. Less glamorously, garbage is dumped into another system of tunnels, so that the visitors never see garbage being transported through the park.

Information systems may have data stored in multi-dimensional arrays. One, or two or three dimensions may be visible to the customer (or to the customer service employee) and the rest of the structure is hidden, but helps make the data available.

Similarly, 3-dimensional networks of business relationships are faster to respond to the needs of one member than one and two-dimensional systems.

Principle 18. Mechanical vibration. Cause an object or system to oscillate or vibrate. Increase the frequency of vibration. Use an object's resonant frequency. Use piezoelectric vibrators instead of mechanical ones. Use combined ultrasonic and electromagnetic field oscillation.

Technological examples: The vibration of a mobile telephone can be used instead of voice alarm. Object's resonant frequency is used for destruction of gallstones or kidney stones by ultrasound in a technique called lithotripsy that makes surgery unnecessary. This can also be seen as the use of segmentation, since the stone breaks itself into very small pieces, which the body then eliminates through its natural processes.

Coordination is an analog of mechanical vibration, applicable in organizations, too. An example: Working time and transportation schedules can be differentiated and coordinated to decrease traffic congestion. Some people have also used vibration as a metaphor for putting a system in an excited state, and applied principle 18 to various ways of exciting people to get coordinated action—examples range from cheerleaders at sporting events, doing “the wave” at sporting events, playing music at political rallies, etc.

Principle 19. Periodic action. Instead of continuous actions, use periodic or pulsating actions. If an action is already periodic, change the periodic magnitude or frequency. Use pauses between impulses to perform a different action.

In Whirlpool's washing machine the pump pulsates. The company claims that the resulting wave effect removes dirt 40-60 % more effectively than a conventional device.

Instead of a continuous light signal, flashing light is often used for information, advertising and warning.

Researchers propose that taking naps in the middle of day will increase the efficiency of intellectual work.

Electrical energy for lighting and work is used mainly in the daytime. Power companies are trying to get people to change the amplitude of the periodic action using financial incentives to stimulate moving power consumption to the nighttime. In warehouses, electric forklifts are programmed to recharge themselves between 2AM and 5AM because that is when power is least expensive.

Pauses in work can be used for training.

Principle 20. Continuity of useful action. Carry on work continuously; make all parts of an object or system work at full load, all the time. Eliminate all idle or intermittent actions or work. Note that these last two principles contradict each other—if you eliminate all intermittent actions, you won't have any pauses to use! This just emphasizes that the various suggestions in each principle must be applied with common sense to the particular situation you are working with.

The changing character of manufacturing shows considerable influence of this principle. Lean and Just-in-Time manufacturing both emphasize small, customized production runs instead of long series.

Some examples: Continuous casting of steel and other metals. Study during traveling.

Mechanical typewriters produced all lines in the same direction (depending on the language being written) with no writing during the time it took to return the carriage to the starting position. Electric typewriters with memory astonished the world when they showed the increased productivity of writing in both directions, eliminating the pauses between lines.

Principle 21. Hurrying. Skipping. Conduct a process, or certain stages (e. g. destructible, harmful or hazardous operations) at high speed.

In surgery, it is well known that the longer the patient is anesthetized, the higher the risk of failure and future complications. Open-heart surgery that once took 8 hours or more is now done in less than one hour, using combinations of new tools and methods.

A classical example of this principle is cutting plastic pipe very quickly. If you cut it slowly, heat from the cut region will propagate into the rest of the pipe, making it change shape.

The traditional method for pasteurizing milk is to heat it to 72 °C or 161 °F for 15 seconds. To increase the storage time of the product ultra-high temperature pasteurization can be used. Milk is heated to higher temperature, for example to 138 °C or 280 °F, for only 2 seconds.

In business it may be sometimes more important act quickly than to make things with no mistakes but slowly. JR Watson, IBM founder put it as follows: "If you want to succeed, double your failure rate." Some companies have gone too far in introducing products or systems that were not fully tested, causing great difficulties for their customers.

Project management and personal time management are examples from business. Sometimes hurrying is the most reasonable way (write a report or letter from the beginning to the end without pauses). If the work is big, it can be done only in parts (periodic action).

Principle 22. "Blessing in disguise". "Turn Lemons into Lemonade". 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.

Electric charges that are usually harmful can be used for the control of process. Charges can cause fires and explosions, destroy electronic components, make materials stick and do other harm. The same charges, present in most industrial processes, can give valuable information for the optimization of process. In coal firing, the measurement of electrical charges on coal dust are used to control burning, decrease harmful nitrogen oxide emissions, and improve efficiency. In cement and lime grinding the product quality can be improved.

Thermal expansion is often harmful and requires compensating devices, but sometimes it can be used to make a strong and reliable joint without fixing components. See the principle "thermal expansion" (37).

In the organization, complaints and destructive critique are negative "charges". They can be used to create positive change in the organization.

"Singing the blues" is an example, too. The singer turns his personal hardship into entertainment for others.

Virus attacks in computer networks are never good, but each time the system survives an attack, information is generated that makes the system better protected from the next attack. This is similar to the way the body works—surviving an illness generates antibodies that protect the victim from the next attack.

There are many social examples how people have turned lemons into lemonade. The founder of TRIZ and author of the forty principles, Genrich Altshuller, begun his work in Baku in 1940s, in the former USSR at the time of Stalin. The administration "rewarded" his activity by some years in work camps. There, Altshuller met many high quality experts arrested during the great purges in the 1930s. He asked them to give classes and seminars. He established a "university" with one student and many professors. This way Altshuller obtained encyclopedic knowledge, which he used to develop tools for problem solving.

During the 1940's, one problem for combat aircraft was the potential explosion of gasoline, when gasoline fumes mixed with air in partially empty tanks. Carrying an inert gas to fill the empty space in the tanks would require extra weight and complexity. In that case, another resource was used—the exhaust gases from the engine were produced onboard the aircraft, and had much less oxygen than ordinary air. The exhaust gases were pumped into the tank and prevented the explosive mixture from forming.

Setting "backfires" is a well-known technique for fighting forest fires. Controlled fires are set ahead of the fire being attacked, to use up the fuel. When the fire reaches that area, it goes out.

Principle 23. Feedback. Introduce feedback (referring back, cross-checking) to improve a process or action. If feedback is already used, change its magnitude and/or influence.

A technical example: In a typical car a driver makes observations and use the steering mechanism, brakes and other "actuators" to make necessary corrections. In new designs under development the car has an active driver-assistance systems with feedback. If the driver, for example, takes the curve too fast, the system turns the steering wheel automatically. .

The evolution of measurements and control is another example. On-line measurements and on-line control is increased. Quality control in production is improved by introducing the immediate measurement and control during the production process, compared to inspection after production. In business, systems for getting feedback from customers are being continuously improved.

Feedback is a primary learning mechanism. Both babies and adults use it naturally, without thinking. A person tries something new. She examines the result. If it was successful, she does it again. If it was not successful, she modifies it, then tries it again. This applies to people learning TRIZ, and to a baby learning to walk, and to all other kinds of learning.

Principle 24. Intermediary. Use an intermediary carrier article or intermediary process. Merge one object temporarily with another (which can be easily removed)

Fixtures or jigs are used to position parts to make assembly easy. The assembled parts are removed, and the jigs are used over and over again. This concept is applied in the home as well as in the factory—a baking pan or a gelatin mold is an “intermediary” for shaping a dessert, while a potholder is an intermediary for carrying a hot dish to the table without burning the server’s hands.

Ice can be used to hold small components in place temporarily, if they will not be harmed by water when the ice melts.

A neutral third party can be used as an intermediary during difficult negotiations. For sales promotion, an intermediary who is seen by the customer as an impartial expert can make recommendations.

Principle 25. Self-service. Make an object or system serve itself by performing auxiliary helpful functions. Use resources including energy and materials, especially those that were originally wasted, to enhance the system.

The tire repairs itself. There are liquids that are sprayed inside tire. When the tire is punctured, the liquid fills the hole. When it contacts the outside air, it solidifies, forming a permanent repair.

A classical example of self-service in business is the self-service fast food restaurant. Many electronic business ideas are based on including the customer and the customer’s resources in the system as resources of the system—this includes everything from communities of interest and chat rooms to data exchanges like Napster and Gnutella.

Some search engines use the frequency of use of a web site as the indicator of quality, so, the more often a site is used, the higher it rates on their recommendation list. This is a combination of feedback (24) and self-service.

Self-treatment and self-test. Patients themselves can perform some medical tests, like the measurement of blood pressure, or blood sugar, or testing for fertility (then later testing for pregnancy) previously done only by medical personnel. In some cases, the patient also adjusts his/her treatment or behavior based on the test results.

Principle 26. Copying. Instead of an unavailable, expensive, or fragile objects, use simpler, inexpensive copies. Replace an object or system or process with optical copies. If visible optical copies are already used, move to infrared or ultraviolet copies.

Make measurements from an image instead of directly. This includes a wide spectrum of technologies, from satellite photographs of farm and timber resources to ultrasonic images of a fetus in the womb.

Use a simulation instead of the object. This includes both physical and virtual simulations such as

- Virtual prototypes instead of physical ones
- Video-conferencing instead of travel
- Virtual reality to test new processes

Fake furs and leathers are also examples of the copying principle. Artificial, fake grass might be an acceptable alternative in some places.

Make images in infrared to detect heat sources, such as diseases in crops, or intruders in a security system.

Use ultraviolet photos to image locations of skin lesions.

Principle 27. Cheap disposables. Replace an expensive object with multiple inexpensive objects, compromising certain qualities (such as service life or appearance, for instance).

Disposable paper and plastic tableware is an example.

Disposable surgical instruments

Disposable protective clothing

Principle 28. Mechanical interaction substitution. Replace a mechanical means with a sensory (optical, acoustic, taste or smell) means. Use electric, magnetic and electromagnetic fields to interact with the object. Change from static to movable fields to those having structure. Use fields in conjunction with field-activated (e. g. ferromagnetic) particles.

The best-known example of the use of a smell as a warning is the incorporation of bad odors into natural gas, to warn users when the system has a leak.

The Just-in-time manufacturing systems use Kanban cards or objects such as portable bins to indicate visibly when supplies are needed.

The history of technology is full of examples in which the mechanical means of doing something is first supplemented by an electrical system, then replaced by an electrical or electronic system. Car steering today is mainly mechanical, but control by wire (already used extensively in aviation) is intensively studied in automotive industry. In telecommunications, infrared and radio waves and other wireless technologies are increasingly replacing mechanical (wired) attachments.

In communication and business we also see clearly the increase of new interactions. In the beginning of human society, all communication was face-to-face communication, which has been augmented by writing, telegraph, telephone, fax, e-mail, videoconferencing and other means.

Transition to better controllable interactions is often associated with transition to the micro-level or segmentation. In jet printers ink particles are controlled by thermal or electromagnetic fields. In displays text and figures are produced, changed and removed using electromagnetic fields to control micro-particles or molecules—for example, many flat panel computer displays use liquid crystals, in which the image depends on the reflection of light from the molecules, and the reflection is modified by changing the orientation of the molecule.

Principle 29. Pneumatics and hydraulics. Use gas and liquid as parts of an object or system instead of solid parts (inflatable, filled with liquids, air cushion, hydrostatic, hydro-reactive).

“Pneumatics and hydraulics” is one way to transition to the micro-level. Examples of pneumatics are inflatable houses or air houses (stores, exhibition pavilions, sport halls and like), inflatable boats, and moving heavy components with an air cushion

Inflatable components allow the designer to decrease weight without losing strength. Air cushions enable movement of heavy objects with very small energy—they are used instead of mechanical lifting jacks to raise aircraft that are on soft surfaces, such as grass or mud.

Similarly, hydraulic equipment can exert more force than simple mechanical systems of the same size. Replacing a physical cutting blade with a water jet illustrates the “hydraulics” principle of replacing solid objects with liquids.

Business systems use this principle by analogy:

‘Water logic’ versus ‘rock logic’ – fluid, flowing, gradually building up logic versus permanent, hard-edged, rock-like alternatives

Flexible (fluid) organization structure versus old fixed hierarchical structures

Liquidation of assets

Introduction of ‘breathing spaces’ into contracts

Principle 30. Flexible shells and thin films. Use flexible shells and thin films instead of three-dimensional structures. Isolate an object or system from the external environment using flexible shells and thin films.

Paper coatings were historically spread using a blade. One improvement is to transfer coating in the form of thin film on the paper. The paper is more evenly coated.

Medication is dispensed over a period of time by putting thin films that dissolve at different rates around small portions of the medicine. The patient can take one pill, and the medicine will be released into his system over a period of time.

The thinnest film is a single molecule thick. Likewise, the thinnest organization structure is one employee thick. Get faster customer service by having the single employee customer service agent have all the necessary data easily available, so the customer only deals with the single, flexible ‘shell’ of the organization not the whole thing.

Many materials, such as epoxies, have two components that must be kept separate until shortly before use. Packages that have pre-measured portions separated by a thin film that the user can easily break to mix the product make it convenient to use. This also has element of principle 10, prepare in advance.

Heavy glass bottles for drinks are often replaced by cans made from thin metal (aluminum) or thin plastic material. Hydraulics is also used - the pressure of the drink makes the can stiff. Weight is reduced without deterioration of strength.

Principle 31. Porous materials. Make an object porous or add porous elements (inserts, coatings, etc.). If an object is already porous, use the pores to introduce a useful substance or function.

A ceramic filter that is made from hydrophilic porous sintered material simplifies and improves vacuum systems. Water that passes through the filter seals the filter at the same time. The air leak of the conventional vacuum filter is eliminated and the consumption of energy decreased. Similarly, porous ceramics are used in many hazardous waste cleanup systems—the pores can be filled with materials that bind the hazardous substances, and the ceramic particles make it much easier to distribute and remove these materials.

Think of the customer-facing layers of a company as a porous membrane which filters information flow both into and out of the organization

High tech micro-fibers are now well known. Small pores prevent water from passing through, but allow moisture to evaporate. New plasters are less known but not less exciting. They are covered by semi-permeable film. Water, dirt and bacteria are kept out, but excess moisture can evaporate through.

Principle 32. Optical property changes. Change the color of an object or its external environment. Change the transparency of an object or its external environment.

Enzymes producing light can be used for detecting impurities in food.

Toys for pre-school children are packed in transparent packages.

Sunglasses that change the amount of light blocked depending on the brightness of the environment display both principle 32 and principle 25, self-service.

Transparency is both a physical and business term. Changing the transparency - increasing or decreasing it - is one important and often cheap way to improve business. Children want to see the toy; adults want to see that products and the whole production process are safe and ecological.

Business school case studies often cite Johnson & Johnson for their exemplary “transparent” behavior as a form of crisis management. When there was a problem with tampering with their Tylenol product, they immediately recalled the product, and gave the public full information on their actions. Both the speed and the full disclosure of the situation are credited with the product’s recovery, and the company’s excellent reputation.

Porous materials and optical property changes compose a pair of principles that are frequently used together. Porous materials are semi-transparent. A business analogy is the firewall in a computer system. The wall should be transparent for customers and other friends, and should at the same time be impermeable for people who try to steal essential information.

Principle 33. Homogeneity. Make objects that interact out of the same material (or material with identical properties).

In the plastic industry, beads of polystyrene are frequently shipped in bags made of polystyrene. That way, the company that melts the beads can put the whole package, including the bags, into their processing equipment. This saves time—no need to open the bags—and eliminates the need to store and dispose of or recycle the bags.

In food, there are many products that use the idea that the wrapper should have the same properties (be edible) as the contents. Ice cream cones, tacos, and spring rolls are good examples.

New medical plasters act like a second skin. They keep wounds moist. Wounds themselves are moist and heal better in a moist environment. This innovation has an instructive history. From ancient Egypt to Rome and through the Middle Ages wounds were treated keeping them moist. Then this knowledge was forgotten, and rediscovered only in the 1960s.

In business, this principle can be used by analogy. People may be more ready to buy things that remind them of familiar products than those that look very different. We are all familiar with movie sequels. *Godfather* was followed by *Godfather II* and *Godfather III* (and the Rambo series, and the Jurassic Park series, ...)

Principle 34. Discarding and recovering. Make portions of an object that have fulfilled their functions go away (discard by dissolving, evaporating, etc.) or modify these directly during operation. Conversely, restore consumable parts of an object directly in operation.

Biodegradable materials in medicine. Polylactides are used to make dissolvable screws and pins. They can replace titanium screws used by surgeons to mend broken bones. The second operation for the removal of screws is not needed.

The tread of tire can be designed to restore the edges of tread blocks when the tire wears.

Many recovering processes have been used in technology long time. Chemicals used for pulping wood are recovered in a recovery boiler. Environmental requirements will make recovery more popular. For example, water polluted in a process is more and more often purified and recycled back into the process.

In business the project organization is a good example of discarding and recovering. A good project should have an end. The organization will then be dissolved. The members can be use their skills again in new projects. In all work knowledge and skills are updated and improved directly during work, and by re-training.

Principle 35. Parameter changes. 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.

The new medical plaster described in Principle 33 also illustrates a parameter change. A traditional dry plaster is replaced by a moist one. The principles of parameter change, homogeneity, and use of porous materials are combined in this technology.

Distill alcohol by evaporating it out of the mash, transporting it away from the original mix, then condensing it.

Transport oxygen or nitrogen or petroleum gas as a liquid, instead of a gas, to reduce volume.

Powdered paints can be used instead of liquid ones. Powder paint combines the performance of modern latex and silicon-based emulsions with the convenience of the powder. Powder can be easily transported and stored. To get ready to paint, just add water.

In business situations, a parameter change is frequently realized as a policy change. In the past decade, many companies have increased the flexibility of employee benefit programs—instead of having one standard program, employees can design a mix of medical insurance, life insurance, pension plans, etc. Likewise, mass customization systems let customers have much more flexibility in designing products that exactly fit their needs.

Principle 36. Phase transitions. Use phenomena occurring during phase transitions (e.g. volume changes, loss or absorption of heat, etc.). There are many kinds of phase transitions. The most common are solid-liquid-gas-plasma, paramagnetic-ferromagnetic, normal conductor-superconductor, but there are many useful phenomena associated with more exotic transitions as well, such as solid-solid crystallographic changes, superfluidity, antiferromagnetism, etc.

Blasting with solid carbon dioxide can clean surfaces. Impurities will freeze immediately, contract, and loosen easily. The example also illustrates parameter changes (35), thermal expansion (37), and hurrying or skipping (21). Impurities are frozen so quickly the cleaned material doesn't suffer from thermal expansion. The carbon dioxide then sublimates (harmlessly turns into gas), so there is no clean up needed.

Heat pipes are well-known examples of using the phenomena associated with phase transitions. The heat given up and absorbed as the fluid in the pipe transitions from liquid to gas can be used either as a heater or air conditioner, depending on how the system is arranged.

When businesses make structural changes (mergers, acquisitions, or internal changes) the accompanying phenomena are analogous to heat in a phase change—there is lots of confusion! Constructive ways to use this period of disruption include

finding new ways to align business systems with new strategies, forming new alliances with customers or suppliers, and getting rid of obsolete practices.

Principle 37. Thermal expansion. Use thermal expansion (or contraction) of materials. Use multiple materials with different coefficients of thermal expansion.

Thermal expansion can be used to position and fit components, such as a valve in an engine. A component is cooled in liquid nitrogen, contracts, is installed, then expands and fixes itself in position.

If employees are excited ('hot') each can do more in the space that expands to exist between them.

Expand or contract marketing efforts depending on the product's 'hotness' – rate of sales and profitability

Principle 38. Strong oxidants. Replace common air with oxygen-enriched air. Replace enriched air with pure oxygen. Expose air or oxygen to ionizing radiation. Use ionized oxygen. Replace ionized oxygen with ozone.

Oxygen is used for bleaching pulp (for paper production). There are ideas and experiments to use ozone for bleaching.

Cut at a higher temperature using an oxy-acetylene torch.

Treat wounds in a high-pressure oxygen environment to kill anaerobic bacteria and aid healing.

Use Nitrox to extend the time a scuba diver can stay at a particular depth.

Use ionized air to improve the performance of air filters.

Principle 39. Inert atmosphere. Replace a normal environment with an inert one. Add neutral parts, or inert additives to an object or system.

Inert gases (carbon dioxide or argon) are used in welding to prevent oxidation of the material at the weld.

Inert materials are added to detergents to make them easier for consumers to measure. (Did you ever wonder why the box says "97% inert materials"?)

A social analogy of inert atmosphere may be indifference and neutrality. Ignore or neutralize negative and destructive actions (if you cannot turn them positive, see the principle 22). Use neutral arbitrators.

Principle 40. Composite materials. Change from uniform to composite (multiple) materials and systems.

Rubber reinforced with woven cords, reinforced concrete, and glass fiber reinforced plastics are typical technology examples.

The use of nothing (air or vacuum) as one of the elements of a composite is very typical of TRIZ—nothing is an available resource in all situations! Examples include honeycomb materials (egg crates, aircraft structures), hollow systems (golf clubs, bones), and sponge materials (packaging materials, scuba diving suits.) These combine principle 31, use of porous material with principle 40, use of composite materials.

In business we can speak of composite structures as well. Multi-disciplinary project teams are often more effective than groups representing experts from one field. Multi-media presentations do often better in marketing, teaching, learning and entertainment than single medium performances. There are less tangible but not at all less important examples. Fanatic commitment to cleanliness is one famous feature of McDonald's. Consistent preparation of food is another major commitment. These are two principles, or values, or fibers that tie together a loose organization.

The principle of composite materials, or more generally, composite systems, is a good conclusion for this section on using inventive principles. If you have a system, you can improve the result by combining it with another system. Innovative principles are also systems. Composite principles often do better than single ones.