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Possibilities of applying TRIZ methodology elements (the 40 Inventive Principles) in the process of architectural design

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Abstract

This article presents a proposal of using the items of TRIZ methodology in architectural design. The methods which have been adapted for the purpose of architectural design are the Inventive Principles. The Inventive Principles are used to activate creative thinking aimed at solving technical contradictions.
Architecture as a design discipline needs the methods supporting a conceptual design and decision-making processes in all phases of the design process. From this point of view TRIZ methods for unlocking the mind - breaking the conventional thinking is very valuable.
The elements of the TRIZ methodology used in this way facilitate to defining and solving difficult design problems. The result is an effective acceleration of the entire design process, which is extremely important for economic reasons.
Going a step further, you can risk the statement that with today's technology it is possible to create the tools for 3D parametric design based on the Inventive Principles. These kinds of tools built into the specialized software for architects (such as Revit Architecture) will facilitate and accelerate the work of them. This type of solution is the part of the existing direction of the software development, in which the designer's role will be mainly setting goals.
This does not exclude the possibility of using other elements of TRIZ methodology in the process of architectural design. These elements will be the subject of further research.

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1. Introduction

Architecture is an interdisciplinary field. Its domain is both technology and science as well as art. A fundamental aspect of architectural activity is creative architectural design. For this reason architecture as a design field needs supporting conceptual and decision-making processes on all stages of design process [1].

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All designers apply methods of solving design problems, even when they do not suspect themselves of doing so. Mental processes occurring during mulling over are beyond the limits of our knowledge. Intuitively, we take it as a transcendental phenomenon, calling it an enigmatic flashes of genius.

The contemporary state of knowledge on the theory of architectural design process is characterized by many areas which have not yet been discovered. In the context of the creative design, the discovery of the mechanisms that govern these phenomena has become extremely important.

Christopher Alexander (English architectural design theorist) once said: "we have made so many steps on the road to depart from our own unconscious shaping of the built environment that we cannot return to the activity completely intuitive, the spontaneous use of 'unspeakable' knowledge (tacit knowledge) " [2]. Conscious control of the design process is dealt by the design methodology. For most architects – practitioners, methodology seems to be something artificial, something of a "straitjacket" limiting their creative freedom, while in practice the architect's actions often have methodological features.

Almost all designers consciously or unconsciously apply the elements of design methodology, as it is an imminent part of the design process. Exploring the techniques and methods assisting this process increases the efficiency and quality of projects being developed. For this reason widening the range of available design methods is very important for architects.

Methodology that can be applied in the process of architectural design is TRIZ design by Genrich Saulovicz Altszuller [3]. It is a set of methods in the theory of innovation that have been created as a tool to assist inventors in various fields. The TRIZ methodology includes a number of methods that can be used alone or in groups according to a scheme (algorithm) called ARIZ (Algorithm of Inventive Problem Solving). TRIZ methodology is currently used mainly in technology, management and pedagogy. It is characterized by the possibility of comprehensive interdisciplinary applications, and thus enormous versatility. For this reason, the possibility of its application in other areas seems to be endless.

This study concludes that methodological and conceptual support of decision-making processes in architectural design by using the 40 Inventive Principles (element of TRIZ methodology) is possible.

40 Inventive Principles are the result of analysis of 40 000 patent inventions (some sources give a number of 1 200 000 inventions). The analysis showed a pattern - most of the inventions were discovered by the application of 40 Inventive Principle.

The Inventive Principles are intended to activate the brain designer to creative thinking, and show him the direction of finding the most appropriate solution to design task.

The aim of cognitive considerations is to improve the architectural design process by using elements of the TRIZ methodology and in particular the 40 Inventive Principles.

2. How to use the 40 Inventive Principles

In order to use the Inventive Principles one should follow the scheme listed below:

2.1. Setting of Ideal End Result (IER) and contradiction (conflict in the system).

The first step in solving design problems is to determine the Ideal End Result (IER) and define the contradiction inherent in the analyzed problem.

The Ideal End Result (IER) is a system self-performing an action (or fulfilling the functions assigned to it) without unnecessary losses (costs, energy, substance, time). The optimal solution is when the new system does not exist but the function of this system is executed (using the resources that we have already had). IER should only use the available resources (tools, facilities, systems, materials, and fields). The correct definition of IER is not possible without taking into account and eliminating the psychological inertia.

A contradiction occurs when a beneficial effect causes harmful effects at the same time. G.S. Altszuller defined two categories of contradictions:

– The technical contradiction (often concerns the entire system)

– Physical contradiction (refers to physical characteristics in the system e.g. temperature). One should find a contradiction and define it:

An attempt to eliminate or reduce the harmful action X causes the weakening of the desirable operation Y.

2.2. Intensification of the contradiction.

The next step is intensification of the contradiction (this action often indicates the direction and even the concept of the solution):

An attempt to improve the desirable operation Y results in the increase of the harmful effect X. One can choose one contradiction which matches the basic function of the considered system or analyze a few of them at the same time. Simultaneous analysis of several contradictions can lead to the solution of many problems at a time.

2.3. Formulation of contradictions using a list of indicators of the technical system.

One should formulate a defined contradiction using a list of indicators of the technical system (Table 1.) These are the 39 indicators of the technical system which are defined in TRIZ as sources of contradiction.

Table 1. The list of indicators of the technical system.

No.	Indicators of the technical system.
1	Weight of moving object
2	Weight of stationary object
3	Length of moving object
4	Length of stationary object
5	Area of moving object
6	Area of stationary object
7	Volume of moving object
8	Volume of stationary object
9	Speed
10	Force (Intensity)
11	Stress or pressure
12	Shape
13	Stability of the object's composition
14	Strength
15	Duration of action of moving object
16	Duration of action by stationary object
17	Temperature
18	Illumination intensity
19	Use of energy by moving object
20	Use of energy by stationary object
21	Power
22	Loss of Energy
23	Loss of substance
24	Loss of Information
25	Loss of Time
26	Quantity of substance/the matter
27	Reliability
28	Measurement accuracy
29	Manufacturing precision
30	Object-affected harmful factors
31	Object-generated harmful factors

32	Ease of manufacture
33	Ease of operation
34	Ease of repair
35	Adaptability or versatility
36	Device complexity
37	Difficulty of detecting and measuring
38	Extent of automation
39	Productivity

2.4. Selecting Inventive Principles.

The Inventive Principles include the ways of avoiding the defined technical contradictions. To select appropriate Inventive Principles one needs to use the Contradiction Matrix [4].

Simultaneous analysis of several contradictions should start from the Inventive Principles which are common to these contradictions (the chords suggested by the Contradiction Matrix most often).

3. 40 Inventive Principles in Architectural Design

Architectural design involves the coordination of other sectors (such as electricity, installations, construction). In practice, many architects impose solutions to each other. For this reason, some of the examples go beyond the theoretical definition of architectural design.

Inventive Principles deliberately take on a very general form and should therefore always be fitted to the specific conditions of the analyzed problem.

The following examples use Inventive Principles as intended to stimulate creative multidirectional multiplex thinking, or suggest a ready solution.

3.1. Segmentation.

3.1.1. Divide an object into independent parts.

Examples of application:

- Design stages (financial considerations, the size of project teams, project work spread over time)
- Build in phases, so that completed stages of the building earn money for the next stages and in case of remodeling ensure that the normal functioning of the whole building is not interrupted.
- Extract the functional parts such as zoning in tenants area (division between night and day part)
- Apply access control (placing door mechanisms limiting unauthorized access) in order to identify functional parts or improve safety.
- In large buildings, increase the number of field sources (e.g. heating, light, water), place them near the areas which they support.
- Provide road access from different sides (enter more: inputs, doors, entrances, elevators, corridors, stairways).

3.1.2. Make an object sectional.

Examples of application:

- In the interior design elements use retractable or folding elements, e.g. retractable projectors, beds hidden in the walls or suspended ceilings, tables hidden in walls or floors.
- Use folding furniture: chairs, tables.
- Instead of public interiors use semi-public and private ones.

3.1.3. Increase the degree of an object's segmentation.

Examples of application:

- Use panel facades, modular claddings, clinker bricks.
- Increase the variety of large areas by the use of modular cladding of different colors or texture.
- Spice up the facades by the use of additional divisions such as blinds, rustication.
- Large warehouses, shops or offices divided into smaller ones with different parameters (e.g. by temperature).
- In urban planning: decentralize, diffuse, spread evenly single function areas, divide into smaller parcels or functional areas.
- Use modular components such as prefabricated, modular furniture.

3.2. Extraction.

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

Examples of application:

- Separate cumbersome rooms by isolating walls and ceilings, for example: fan rooms, power supply room, welding room, rooms with machines emitting x-rays, paint - shop.
- Locate cumbersome equipment outside of the building - air handling units, compressors, power generators.
- Locate rooms with a cumbersome objects or equipment in separate buildings such as: garbage cans, transformer, and concert halls.
- Design a separate room or separate areas dedicated to functions inconvenient for other users, such as smoking rooms or smoking areas.
- Design a separate room or separate areas for children.
- Separate rooms for increased requirements such as: server rooms - separated electrostatically, conference recordings - acoustically isolated.
- Divide the building into fire zones, depending on the function, fire load, the cost of equipment required in the different fire zones, evacuation conditions.
- In case of interruptions in power supply to the facilities essential for the functioning of the entire building and safety (e.g. escape routes, the server rooms, boiler, etc.), design emergency power generators.

3.3. Local quality.

3.3.1. Transition from a homogeneous structure of an object or outside environment/action to a heterogeneous structure.

Examples of application:

- Develop individual projects taking into account the specific needs of users.
- Use historical events or old function of location for design inspiration(e.g. reveal the foundations of the demolished building, the historic, old city walls, in place of the old wells design a fountain, etc.).

3.3.2. Have different parts of the object carry out different functions.

Examples of application:

- Separate functionally distinct groups of rooms.

3.3.3. Place each part of the object under conditions most favorable for its operation.

Examples of application:

- In representative rooms use better quality materials.
- Increase the intensity of light in the vicinity of work areas (area of windows, skylights, additional artificial light).
- When designing layout of the rooms in the building take into account building orientation towards the world.

3.4. Asymmetry.

3.5. Replace a symmetrical form with an asymmetrical form.

Examples of application:

- Design asymmetric blueprints, facades, of the structure especially if symmetrical solid shapes of the building (blueprints, facades, structure) complicate the functional system.
- From symmetrical shapes (square, rectangle, circle, equilateral triangle, etc.) go to the asymmetric (diamonds, scalene triangles, curved shapes, etc.).
- Cancel the symmetrical composition or increase the degree of asymmetry.
- Use asymmetrical doors to comply with the requirements such as the escape route width.

3.5.1. If an object is already asymmetrical, increase the degree of asymmetry.

Examples of application:

Adapt the building blocks of proposed dimensions and scale to the immediate surroundings, e.g. by varying the height.

3.6. Combining.

3.6.1. Combine in space homogeneous objects or objects destined for contiguous operations.

Examples of application:

- In apartment buildings or town houses use devices which support multiple dwellings, such as garbage chutes, central heating, central vacuum cleaners.
- Locate the spaces that require elevated temperatures next to each other (lesser loss of energy).
- Design garages connected to buildings.
- On narrow plots of land design buildings in twin or serial layout.
- Use sandwich panels as a material on the external walls.
- Design the channels passing through walls and ceilings for the installations.
- Design buildings which blend into the environment in terms of shape, texture, material, for example, if there are rocks in the surrounding area, the building may look similar.
- Designing buildings use colors and patterns taken from the surrounding environment, e.g. if you want to hide a tall chimney the color should be based on the colors of the sky.

3.6.2. Combine in time homogeneous or contiguous operations.

Examples of application:

- Use the sun visors with integrated photovoltaic cells.

- Collect rainwater from the roof, which can be used for example for flushing toilets, watering gardens, washing cars, etc.
- Provide full access to all parts of the building for people with disabilities.
- In conceptual designing look for inspiration in other areas of design, environment, arts.

3.7. Universality.

3.7.1. Have the object perform multiple functions, thereby eliminating the need for some other object(s).

Examples of application:

- Multi-functional room design.
- For people who regularly change residence design mobile homes (houses with wooden framing, mounted on a steel frame or floating homes) that can be move and located in any place.
- Use auxiliary rooms to serve multiple parts of a building or different buildings such as warehouses, closed garages, boiler rooms, fan rooms, switching power, toilets, utility rooms (saving space and energy used for their service).
- As a material for the walls use glass matting under the influence of electricity (called Smart Glass) as a material for the walls. Variable transparency of glass allows you to temporarily reduce their visibility (an example of the application may be separating the bathroom from the bedroom).
- Indoor use stretch ceilings illuminated by LED (they limit the height of the room, they are a source of light, allow any shape to be formed to gain interesting spatial effects).
- Use walls, floors and ceilings as screens for projectors (painted with an appropriate paint).

3.8. Nesting.

3.8.1. Contain the object inside another which, in turn, is placed inside a third object.

Examples of application:

- Use a folding furniture: stackable chairs, tables, containers.
- Use suspended ceilings or stretch ceilings.
- In the interior design use retractable, folding elements, e.g. retractable projectors on the ceiling lifts, beds hidden in the walls or suspended ceilings, tables hidden in walls or floors, built-in wardrobes.

3.8.2. Pass an object through a cavity of another object.

Examples of application:

- In conceptual design to vary the form of the building block use overlapping.
- Use the door hidden in the wall.
- Use a folding attic stairs hidden in the ceiling.

3.9. Counterweight.

3.9.1. Compensate for the object's weight by joining with another object that has a lifting force.

Examples of application:

- As additional structural elements use rods, brackets, e.g. cantilever beams.
- Use elevators.

3.9.2. Compensate for the weight of an object by interaction with an environment providing aerodynamic or hydrodynamic forces.

Examples of application:

- On the land with weak carrying capacity use foundation slabs, foundations on piles or wells.
- Design houses floating on the water (many examples can be found in the Netherlands).
- Design buildings lifted by balloons, airships.

3.10. Prior counter-action.

3.10.1. Perform a counter-action in advance or if the object is (or will be) under tension, provide anti- tension in advance.

Examples of application:

- Use compressed construction components (e.g. pretensioned prestressed concrete), characterized by higher strength and lower weight (e.g. long span floors with low construction height).

3.11. Prior action.

3.11.1. Carry out all or part of the required action in advance.

Examples of application:

- Use materials that do not require additional finishing such as architectural concrete.
- Use prefabricated: ready lintels, beams, columns, floor slabs, cladding panels.

3.11.2. Arrange objects so they can go into action in a timely matter and from a convenient position.

Examples of application:

- Already in the preliminary design phase, plan the use and size of equipment rooms in order to rule out time-consuming changes to the final design stage.
- Design engineering and manufacturing facilities so that the holes in the walls allow the insertion of bulky equipment.
- To build the foundation walls, retaining walls use formwork or concrete blocks.
- When designing use building materials available in the vicinity of the proposed facility.

3.12. Cushion in advance.

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

Examples of application:

- Design the attic flat roof design with auxiliary / emergency overflow (they protect against the effects of large amounts of residual water on the roof).
- Design the lightning protection system on the roofs.
- Design the interior using the elements protecting against mechanical damage, such as in the sport halls or in the corridors of the hospital where beds are often transported.

- While designing elements of the building or of the equipment, make them wider than required by the regulations (during construction works minimal differences in relation to the project may emerge, which may result in the prevention of the use of building).
- During the design of structural elements, remember to include expansion joints, concrete screeds, wall coverings, etc. (they provide protection of the rigid components against damage caused by changing the volume of material in low / high temperature).
- Design wiper systems built into the floor at the entrances to buildings.
- Use air curtains on external doors to reduce losses or excessive heat gains.
- In places that are difficult to access design extra holes and channels (holes in ceilings, holes in walls, under the protective tube passageways, in the walls of the foundation) for additional connections in the future, such as installation (lowering the cost of making changes in the future).
- Locate cumbersome equipment, such as air handling units, compressors, power generators, outside of the buildings.
- Locate rooms with cumbersome objects or equipment in a separate building, e.g. dustbins, power supply rooms, storage of toxic material or concert halls.
- Locate the flood risk areas in the lower levels (this will limit the losses in case of the flooding)
- Locate the premises or equipment prone to explosions away from clusters of people or use appropriate protective barriers.
- Use heating (heating cables under the surface) in the roads and routes prone to icing.
- Use heating cables and mats to to secure the roof from big volumes of snow, ice or formation of icicles on gutters and down pipes
- Apply automatic fire extinguishing systems (sprinkler systems), internal hydrants, automatic smoke removal systems (smoke flap or window) on the escape routes and in the fire hazard areas.
- In order to limit the spread of fire, use fire resistant walls and ceilings, flameproof glass.
- Apply the framework construction which allows for easy changes of the functional system (layout of rooms in the building).

3.13. Equipotentiality.

3.13.1. Change the working conditions so that an object need not be raised or lowered.

Examples of application:

- In factories use moving production lines.
- Design groups of buildings in the same or similar level to enable effective communication between them.
- Use a remote control elements of the building equipment.
- Use the escalators, moving walkways.

3.14. Inversion.

3.14.1. Instead of an action dictated by the specifications of the problem, implement an opposite action.

Examples of application:

- For the location of the building: rather than designing it above the ground to locate facilities underground and have skylights illuminate them from above.
- For the project office: design a table in the floor and put the seats lower.
- Locate pools outside the building (e.g. on the balconies of multi-story building or the roof) rather then inside.

- For the components of the building: instead of driving into the garage on a ramp use cranes which automatically transfer the car to the garage, instead of driving the car into the building, pull out a roof over a car.

3.14.2. Make a moving part of the object or the outside environment immovable and the non-moving part movable.

Examples of application:

- Use the escalators, moving walkways.
- Use automatic sliding, retractable or hinged doors, gates, windows.
- Applied to the whole building or part of thereof (e.g. kinetic architecture stories independently rotating around a vertical axis), such procedures can change the shape of the building, control over the view of the interior and atmospheric conditions such as sunlight exposure, wind direction)
- Use a moving scene in the cinemas and theaters.

3.14.3. Turn the object upside-down.

Examples of application:

- Used to form the whole building or its components (e.g. put the building on its roof), this type of treatment composition attract attention, often produce original and unique solutions which affect the value of the project.
- Instead of hiding the installations inside the building, place them where they would be visible (this type of solution has already been used in the Museum of Contemporary Art Centre Georges Pompidou in Paris).

3.15. Spheroidality.

3.15.1. Replace linear parts or flat surfaces with curved ones; replace cubical shapes with spherical shapes.

Examples of application:

- Design curvilinear plans, building facades especially if simple shape forms complicate a functional arrangement system or make the composition unattractive.
- Design a spherical form of the building in order to improve the functional system or the building blocks or make it stand out against the surrounding environment.
- Design arches, domes, columns.

3.15.2. Use rollers, balls, spirals, domes.

Examples of application:

- Design a multi-storey garages using spiral ramps.
- Design moving walkways.

- When equipping rooms use furniture on wheels.
- Separate space with movable walls.

3.15.3. Replace a linear motion with rotating movement; utilize a centrifugal force.

Examples of application:

- Design a revolving door.

- Design rotary fountain.

3.16. Dynamics.

3.16.1. Make an object or its environment automatically adjust for optimal performance at each stage of operation.

Examples of application:

- Use a mobile (cruise) facade elements for protection against excessive sun exposure (shutters, awnings, blinds, shutters).
- Design automated garages (cranes and mobile platforms themselves parked car).
- Design buildings or their parts as moving elements (e.g. kinetic architecture stories independently rotating around a vertical axis), such procedures allow control over weather conditions such as sunlight exposure, wind direction.
- Design mobile facades (propelled by wind, sunlight, water) in order to provide an attractive visual effects.

3.16.2. Divide an object into elements which can change position relative to each other.

Examples of application:

- Use roofs with varying time geometry (varieties: fold or folds (called folded), developed (called expandable), and mobile or drawn (called retractable).
- Design escalators, moving walkways, elevators, lifts, mobile bridges.
- Design automatic sliding, retractable or hinged doors, gates and windows.

3.16.3. If an object is immovable, make it movable or interchangeable.

Examples of application:

- For people who regularly change residence design mobile homes (houses with wooden framing, mounted on a steel frame or floating homes) that can move and be located in any place.

3.17. Partial or excessive actions.

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

Examples of application:

- If you want more light in the room and on the elevation but there is no space for the windows, design glass doors instead.
- Use a light tunnel to light up the rooms that are located away from exterior walls and roof.
- Instead of artificial lighting systems use more reflective paint (paint containing glass particles) or a fluorescent material.
- To reduce the energy consumption of a building, use recuperators, photovoltaic cells, solar panels, wind turbines, heat pumps etc.
- Design a lace cover to hide items or technical equipment of low aesthetic value (e.g. the control of ventilation, tanks, bins).
- In the new housing do not design the paths between the buildings in the first stage, residents will tread the most convenient pedestrian routes which in the second stage could easily be hardened.
- Instead of costly design windows or skylights replace sphere with glazing polyhedron.

- Instead of individual projects use projects ready to use, typical solutions.
- Instead of atypical materials use available.
- In case when the typical materials and designs are not available or do not exist, offer individual solutions.

3.18. Moving to a new dimension.

3.18.1. To move an object in two- or three-dimensional space.

Examples of application:

- Locate rooms used occasionally in other parts of the building or on different floors.
- To design buildings or their moving parts vertically.

3.18.2. Use a multi-story arrangement of objects instead of a single-story arrangement.

- Design a multi-storey garages instead of flat ones.
- Design multi-storey buildings instead of one storey.
- In the interior design use mezzanines, bunk beds, furniture split horizontally.

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

Examples of application:

- Design sloping walls or entire blocks of buildings for example to increase the dynamics of the spatial composition.
- Design a sloping roofs.
- Use furniture such as reclining chairs, sofas and tables in interior design.

3.18.4. Use 'another side' of a given object.

Examples of application:

- Design windows, doors as Venetian mirrors especially when we want to limit visibility from one side (e.g. the window between the bedroom and bathroom, in the interrogation rooms, store rooms).
- Design a roll-away beds from the ceiling, pulled from the wall.
- Use the streams of light falling on a neighboring property or on the reverse side of an essential facility.

3.18.5. Use 'another side' of a given area.

Examples of application:

- To light up the rooms that are located away from exterior walls and roof use a light tunnel.
- Use reflecting surfaces (mirror optics), e.g. glass mirrors, mirrors of water, polished metals to achieve attractive visual effects on the body of the building, elevation or the interior of the building.
- Design a colorful translucent reflective elements or artificial sunlights to obtain attractive optical effects on the body of the building, elevation or the interior of the building methods are here understood as a methods known and used by architects in other areas.

3.19. Mechanical vibration.

3.19.1. Cause an object to oscillate or vibrate.

Examples of application:

- Design buildings or parts of the moving parts (e.g. kinetic architecture storey's independently rotating around a vertical axis), such procedures enable the control of the weather conditions such as sunlight and wind direction.
- Design moving elevations (moved by wind, sunlight, water) in order to create attractive visual effects.

3.19.2. If oscillation exists, increase its frequency, even as far as ultrasonic.

Examples of application:

- Use wind turbines for producing power.

3.19.3. Use the resonant frequency.

Examples of application:

- Use porous materials with irregular shapes, in concert halls on the walls and ceilings to design non- parallel walls to prevent the formation of acoustic standing waves.
- Use vibrators for compacting soil (under foundations) or concrete to obtain the best mechanical properties.
- Design special foundations and supporting structures in the areas threatened by earthquakes.

3.19.4. Use ultrasonic vibrations in conjunction with an electromagnetic field.

Examples of application:

- Use artificial fog (produced by ultrasound) to hide the building or its part or create a special atmosphere of the place (this solution was applied by Diller & Scofidio Office in Blur Pavilion, Zaragoza).
- Design voice or electromagnetic elements for building equipment.
- Use ultrasonic devices for the evaluation of existing buildings.

3.20. Periodic action.

3.20.1. Instead of continuous action, use periodic or pulsating actions.

Examples of application:

- Use automatic systems of lighting and heating.
- Use energy saving light sources operating periodically, such as fluorescent lamps.
- Design repetitive elements of the composition in the rhythm (e.g. columns, pillars, elevations panels).

3.20.2. If an action is already periodic, change its frequency.

Examples of application:

- Design the control of mechanical ventilation integrated with lighting.
- Use motion sensors to control lighting, automatic doors, etc.

- Interrupt the rhythm of repetitive elements in the composition in order to highlight important sites (such as the rhythm of coloristic accents on the surface or elevation).

3.20.3. Use pulsed between impulses to provide additional action.

Examples of application:

- Design public toilets as automatic, self cleaning devices (an automatic cleaning process starts after each use).
- Include the requirements of automatic cleaning equipment in projects, such as elevations and floor cleaning equipment.

3.21. Continuity of useful action.

3.21.1. Carry on work continuously; make all parts of an object work at full load, all the time.

Examples of application:

- Design sports halls, conference rooms, restaurants, concert halls as frequently used multifunctional rooms.
- Design multi-storey garages for multiple-use buildings at different times of the day and night.
- Design a secondary power supply in areas relevant to the functioning of the entire building and safety of workers, e.g. escape routes, a server room, a boiler room, etc.
- Use multifunctional devices such as multifunctional boilers.

3.21.2. Remove idle and intermediate motions.

Examples of application:

- Establish all the factors before the start of design work (regulations, financing, terms, limitations of space, the scope of work).
- Design following the order of priority and availability of the individual functional parts, e.g. locate trade on the ground floor.

3.22. Skipping.

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

Examples of application

- Design using prefabricated components to shorten the construction time.
- Design in multiple teams to shorten the working time.
- Generate the computer visualization of architectural concepts on multiple computers.
- Divide the project into independent parts and outsource a design documentation for outside companies.

3.23. Convert harm into benefit.

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

Examples of application:

- Use the rainwater removed from the roof for flushing toilets, watering gardens, washing cars, etc.

- In buildings located in the hot climate, use solar power, e.g. use photovoltaic cells to produce electricity in order to power the equipment for ventilation and cooling of the rooms, use solar panels to heat water.
- Use the rubbish in the factories which produce a lot of it for heating the building.
- Use the sun visors integrated with photovoltaic cells.
- Take advantage of the difficult location (e.g. on a mountain slope, a waterfall) in order to enhance the attractiveness of the spatial composition of the building.
- Use the existing elements of the plot (such as trees, other plants, monuments, historic buildings, reservoirs, rivers) as the important elements of the composition of the designed space (buildings along with the surroundings, interiors).

3.23.2. Eliminate the primary harmful action by adding it to another harmful action to resolve the problem.

Examples of application:

- Use self-cleaning glass on the external walls (a special coating of UV sunlight causes the degradation process of impurities on the glass, then the rainwater washes the dirt).

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

Examples of application:

- Design a building block in such a way so that the drafts could be formed between them which gives the possibility to locate the energy-producing wind turbines.

3.24. Feedback.

3.24.1. Introduce feedback to improve a process or action.

Examples of application:

- In public spaces (squares, public buildings) design interactive multimedia walls (responding to the voices and movements of people who are in the vicinity) to enable the communication with people in similar areas.
- Use the equipment recovering the energy, e.g. recuperators (heat recovery from the air expelled from the building).
- Integrate the ventilation of the rooms with their lighting.
- Integrate the lighting with the motion sensors.
- Coordinate industry projects in order to eliminate the collisions between them.
- Design automatic fire extinguishing systems (sprinklers), automatic smoke removal systems (smoke flaps or windows).

3.24.2. If feedback is already used, change its magnitude or influence.

Examples of application:

- Limit the investor's legal commitment to design procedures by obtaining the authorization.
- Limit the number of designers contacting the investor (it will affect the coordination of the arrangements and the image of the design office).

3.25. Mediator.

3.25.1. Use an intermediary object to transfer or carry out an action.

Examples of application:

- Design atria at the building entrances (air locks), limiting the losses of heat or excessive heat gains
- Design the connectors between buildings or their parts in order to facilitate the communication.
- While designing include expansion joints of structural elements, concrete screeds, wall coverings, etc. (in order to prevent the damage to rigid components while changing the volume of material under the influence of temperature).
- In order to prevent the fume in case of fire use fire vestibules with smoke doors.
- Use the light tunnels, skylights in order to light the rooms located away from the exterior walls and roof.
- While designing, take into account the elements of visual and acoustic communication.

3.25.2. Temporarily connect an object to another one that is easy to remove.

- Use smoke curtains in high production halls and warehouses (curtains suspended from the ceiling limit the spread of smoke) to facilitate the rapid removal of smoke.

3.26. Self-service.

3.26.1. Make the object service itself and carry out supplementary and repair operations.

Examples of application:

- Use the lamps with light sensors (they regulate the power of light by themselves, depending on the ambient conditions, which reduces the energy consumption).
- Use photo chromatic glass in the windows.
- Use heavy insulations from bentonite as water insulations in areas subjected to water pressure, (material swelling in contact with water, as a result, stop little damages).
- Design automated garages (cranes and mobile platforms which park cars by themselves).
- Design public toilets as automated self cleaning devices (an automated cleaning process starts after each use).
- Use self-cleaning glass at the external walls to (a special coating under the influence of UV sunlight causes the degradation process of impurities on the glass and then the rainwater washes the dirt).
- Use self-cleaning paint on facades (zolo-silicate paints with the effect of photocatalysis).

3.26.2. Make use of wasted material and energy.

Examples of application:

- Use the equipment recovering energy e.g. recuperators (heat recovery from the air expelled from the building).
- Use the rubbish in the factories which produce a lot of it to heat the building.
- Use intelligent energy management systems in buildings (they control sunblind, heating, lighting, ventilation).
- Use the equipment for the purification of waste water e.g. small treatment plants.
- Use the rainwater removed from the roof for flushing toilets, watering gardens, washing cars etc.

3.27. Copying.

3.27.1. Instead of an unavailable, expensive, fragile object, use simpler and inexpensive copies.

Examples of application:

- Use cheaper construction techniques such as the Canadian backbone technology instead of brick one.
- Use stoneware tiles or ceramic tiles instead of more expensive stone slabs as lining or finishing layer.
- While designing furniture use cheaper boards with laminates which imitate more expensive materials such as solid wood, aluminum.
- Use panels as a finishing floor layer instead of wooden planks and parquet.

3.27.2. Replace an object by its optical copy or image. A scale can be used to reduce or enlarge the image.

Examples of application:

- While designing use specialized 3D software.
- Use computer visualizations in contacts with the investor.
- To enliven the surface of the buildings (facades, walls, floors, ceilings) show the images from the projector on them.
- Designing the interior use wallpaper and photo wallpaper.
- Use matting under the influence of electricity glass as the inside walls (variable transparency of glass allows you to reduce their visibility temporarily, an example of the application may be separating the bathroom from the bedroom).
- Design interactive multimedia walls in public spaces (squares, public buildings) making possible for communication with people who are in similar places, or reacting to the movements and voices of nearby people.

3.27.3. If visible optical copies are already used, move to infrared or ultraviolet copies.

Examples of application:

- Use infrared cameras to detect thermal bridges in the existing buildings.

3.28. Cheap short-living objects.

3.28.1. Replace an expensive object by a collection of inexpensive ones, forgoing properties (e.g. longevity).

Examples of application:

- Design temporary buildings from cheaper and less durable materials.
- Use cheaper construction techniques, e.g. the Canadian backbone technology instead of brick technology.
- Take advantage of cheaper platform screw lifts instead of more expensive hydraulic ones.
- Apply stoneware or ceramic tiles as a lining or finishing layer instead of more expensive stone slabs.
- While designing furniture use cheaper boards with laminates that imitate more expensive materials such as solid wood, aluminum.
- Use panels as a finishing layer of the floor instead of wooden planks and parquet.
- Use cardboard furniture.
- Thermal insulating paint should be used instead of conventional thermal insulating materials (such as: styrofoam, wool), especially in historic buildings.

3.29. Replacement of a mechanical system.

3.29.1. Replace a mechanical system by an optical, acoustical or olfactory system.

Examples of application:

- Provide voice control (to unlock doors, gates, to control lighting, television, an audio system), it is especially important if the users of the building are blind.
- Introduce an optical control in elevators, doors, blinds (motion detectors, dusk sensors).
- Use voice evacuation systems in buildings, e.g. a fire alarm.

3.29.2. Use an electrical, magnetic or electromagnetic fields for interaction with the object.

Examples of application:

- Control doors, gates by the use of induction loop (induction loop detects a metal object located above it).
- Use the magnetic devices which detect the existing installations inside the building.
- Use fire protection systems using electromagnetic control.

3.29.3. Change from static to movable fields, from unstructured fields to those having structure.

Examples of application:

- Use control access systems for rooms or building control equipment based on biometric readers.

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

Examples of application:

- Use control access systems or building control equipment based on electromagnetic readers.

3.29.5. Pneumatic or hydraulic construction.

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

Examples of application:

- In large facilities (e.g. sports halls), used temporarily or seasonally, use pneumatic roof covering (roofs from textile membranes supported by high air pressure).
- Use air curtains at external doors, thus reducing heat losses or excessive heat gains.
- Use pneumatic or hydraulic jacks to the moving parts of the building.
- Design double façades with a ventilated space that separates them.
- Use inflatable furniture or furniture filled with water in the interior design.

3.30. Flexible membranes or thin film.

3.30.1. Replace traditional constructions with those made from flexible membranes or thin film.

Examples of application:

- In large facilities (e.g. sports halls), used temporarily or seasonally, use pneumatic roof covering (textile roofs supported by pressure).
- Design stretch walls and ceilings inside (from flexible PVC material), which feature is the ability of shaping spatial forms.
- To light the rooms located away from the exterior walls and roof use flexible lighting tunnels.

3.30.2. Isolate the object from the external environment using flexible membranes or thin film..

Examples of application:

- Use the façade grids that reduce the chilling of the elevations by weakening the wind strength, that improve the aesthetics of the building, and can function as a screen for projection of colorful images.
- Use the roofs with varying time geometry (varieties: folded, expandable, retractable).

3.31. Porous material.

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

Examples of application:

- Use porous surface materials improving room acoustics (sound scattering) in areas with higher acoustic requirements.
- Used blocks which feature is the low weight as the building material.
- Use porous building materials, e.g. LECA-concrete, as structural components of ceilings and walls.
- Use porous materials as insulation, e.g. extruded polystyrene (foam has a homogeneous structure).
- Use the façade grids that reduce the chilling of the elevations by weakening the wind strength, that improve the aesthetics of the building, and can function as a screen for projection of colorful images.

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

Examples of application:

- Use inside travertine slabs filled with resin, acrylic, or epoxy as stone lining.
- To make the composition of facades and flat surfaces more attractive, use different texture elements (e.g. use polished accents in large matt planes and vice versa).

3.32. Color changes.

3.32.1. Change the color of an object or its external environment.

Examples of application:

- Use stretch ceilings and illuminated LED as indoor ceilings (they allow to obtain various shapes and colors of the surface which generate the interesting effects of the interior design).
- Use walls, floors and ceilings as screens for projectors (painted with an appropriate coating), such a solution can generate attractive visual effects.
- Apply colouristic accents on the monotonous surface.

3.32.2. Change the transparency of an object or its external environment.

Examples of application:

- Use glass matting under the influence of electricity as walls (called Smart Glass), the variable transparency of glass allows you to reduce temporarily their visibility, an example of the application may be separating the bathroom from the bedroom.

3.32.3. Use colored additives to observe objects or processes which are difficult to see.

Examples of application:

- Use infrared cameras to detect thermal bridges in existing buildings.

3.32.4. If such additives are already used, employ luminescent traces or tracer elements.

Examples of application:

- Introduce fluorescent material (e.g. as elements of interior design, to improve the visibility of the visual communication or for the safety - marking escape routes, stairs).

3.33. Homogeneity.

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

Examples of application:

- In public spaces (squares, public buildings) design interactive multimedia walls (responding to the voices or movements of people in the vicinity) to enable communication with people in similar areas.
- Use system solutions (e.g. materials from the same manufacturer are compatible).
- Design adjoining parts from the materials with the same or similar properties.
- Apply homogeneous finishing materials for designing the group of objects.
- Design buildings with large floor space as assemblies of smaller buildings matching functionally, compositionally, stylistically and coloristic.

3.34. Rejecting and regenerating parts.

3.34.1. After it has completed its function or become useless, reject or modify (e.g. discard, dissolve, evaporate) an element of an object.

Examples of application:

- Use an unused effluent tank (after connecting the building to the sewerage system), or a dried well as a rainwater tank.
- Design temporary buildings from cheaper and less durable materials used from recycling.
- Use the furniture made of cardboard.

3.34.2. Immediately restore any part of an object which is exhausted or depleted.

Examples of application:

- Use heavy insulations from bentonite as water insulation in the areas subjected to water pressure, (swelling material in contact with water heals will fill in little holes).
- Use self-cleaning glass at the external walls to (a special coating under the influence of UV sunlight causes the degradation process of impurities on the glass and then the rainwater washes the dirt).

3.35. Transformation of the physical and chemical states of an object.

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

Examples of application:

- Ice may be a building material, e.g. for igloos.
- In order to achieve a rigid object connection, you can freeze the water between them.

3.35.2. Change the concentration or consistency.

Examples of application:

- Use concrete mixed with aeration (micro bubbles reduce its absorption and increase the frost resistance of concrete by which it improves its resistance to weather conditions).
- Use compressed components (e.g. pretensioned prestressed concrete, posttensioned prestressed concrete), characterized by higher strength and lower weight (e.g. long span roofs, and also low-level design).
- Use glued wood with better parameters such as strength, fire resistance, durability instead of solid wood.

3.35.3. Change the degree of flexibility.

Examples of application:

- Use concrete with scattered reinforcement in order to eliminate micro-cracks and shrinkage cracks.
- Use laminated safety glass.
- Apply epoxy floors in areas with higher chemical resistance requirements.

3.35.4. Change the temperature.

Examples of application:

- Use quenched steel with higher mechanical strength.
- Use hardened safety glass having higher mechanical strength.

3.35.5. Change the pressure.

- In the case of flat roofs, drainage divisions (piping away the rainwater from the roof) complicate the functional layout of the premises located beneath them. The use of vacuum drainage systems allow to drain water in pipes on the level without declines (this enables the location of any soil pipes).
- Use compressed components (e.g. pretensioned prestressed concrete, posttensioned prestressed concrete), characterized by higher strength and lower weight (e.g. long span roofs, and also low-level design).
- Locate sewerage pumping stations in places below the level of plumbing.

3.36. Phase transitions.

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

Examples of application:

- Divide the design process into phases (conceptual design, construction design, executive design).
- To reduce the energy consumption of the building use recuperators, photovoltaic cells, solar panels, wind turbines, heat pumps etc.
- In case of interruptions in power to facilities essential for the functioning of the entire building and safety (e.g. escape routes, a server room, a boiler room, etc.), design of emergency power generators.
- Use infrared cameras to detect thermal bridges in existing buildings.

3.37. Thermal expansion.

3.37.1. Use thermal expansion (or contraction) of materials.

Examples of application:

- In large facilities (e.g. sports halls), used temporarily or seasonally, use pneumatic roof covering (textile roofs supported by pressure).

3.37.2. If thermal expansion is being used, use multiple materials with different coefficients of thermal expansion.

Examples of application:

- Design reinforced concrete structures to enhance the strength of concrete and steel protection from high temperatures.
- Design the windows automatically opened by the bimetallic plates in the buildings where there are large temperature differences (glasshouses).

3.38. Strong oxidants.

3.38.1. Replace normal air with enriched air

Examples of application:

- Use the windows with inter-glass spaces filled with gas, e.g. argon or krypton, this set considerably increases thermal insulation around the windows.

3.38.2. Replace enriched air with pure oxygen.

Examples of application:

- While designing industrial buildings and hospitals, include channels for distributing oxygen and all the necessary equipment.

Examples of application:

- Include the radiation equipment and the radiological protection in the designs for health care buildings and medical laboratories (departments of radiotherapy, nuclear medicine).

3.38.3. Use ionized oxygen.

Examples of application:

- Include equipments for ozonation (antibacterial) in designing food storages, food processing factories and hospitals.

3.39. Inert environment.

3.39.1. Replace a normal environment with an inert one.

Examples of application:

- Designing industrial residential and service buildings, strive to create the optimal conditions for their employment, housing, leisure, by appropriate choice of parameters of the built environment such as lighting, ventilation, etc.
- Perform the structures made in the water by caisson (they are capable of performing earthworks inside the box located under water).

3.39.2. Carry out the process in a vacuum.

Examples of application:

- Use vacuum chambers as thermal isolation (e.g. the windows with the vacuum space between the glasses).

3.40. Composite materials.

3.40.1. Replace a homogeneous material with a composite one.

Examples of application:

- Use composite structural materials such as reinforced concrete, plastic and carbon fiber composites.
- To improve the aesthetic values, use the inserts from other materials on the monotonous surfaces (facades, floors, slabs).
- Design the elements exposed to the aggressive environment from composite materials, e.g. replace timber exposed to the weather conditions by a combination of wood and PVC.
- Use laminates as durable finishing elements such as HPL.

4. DISCUSSION AND CONCLUSIONS

TRIZ methodology is one of the few former Soviet Union export goods, which are spreading faster and faster around the world, especially in developed countries (such as the Germany, Austria, France, USA, Japan, South Korea, etc.), to some extent also in Poland. Its effectiveness is the source of the success of many companies (such as Samsung, Ford, Motorola, Siemens, Philips, etc.) which base on the introduction of innovative products.

Architectural designs are increasingly seen as the goods for sale. Many analogies to designing a new product in technics can also be found in the architectural designing process. As in the case of designing a new product, the value of architecture projects depends on their quality and degree of innovation.

In the future, the further dynamic development of the Internet, use of methodic design will be decisive for the competitiveness of the designers in the global market orders.

Going a step further, you can venture to say that with today's technology it is possible to create the tools for 3D parametric design based on Inventive Principles. Such tools integrated with specialized software for architects (e.g. Autodesk's Revit Architecture) will further facilitate and accelerate the work of architects.

The introduction of elements of TRIZ methodology to computer programs that support the activities of architects on the short term may be common because the solution is part of the existing direction of the professional software for architects, where the role of the designer's target is to be mainly setting goals. Perhaps this will result in a systematic innovation process of architectural design.

The main function of the TRIZ methodology is to unlock (activate) creative thinking in order to allow proper formulation and solve difficult design problems. As a result, we obtain an effective acceleration of the entire design process. Therefore, the use of elements of TRIZ methodology in the creative architectural design is likely to accelerate the progress in this field. Shortening the work time on the project is also extremely important for economic reasons.

The elements of TRIZ methodology (40 Inventive Principles) may be a "salvation" for architects using only routine, repeatable solutions (the architects trapped in the project diagrams).

These examples show that the TRIZ methods, particularly Inventive Principles, can assist conceptual and decision-making processes in architectural designing. Perhaps that further work on the possible use of 40 Inventive Principles in architectural designing may bring further positive results.

Therefore, the use of the other elements of TRIZ methodology cannot be excluded in the process of architectural designing. It will be the subject of further researches related to the practice of architectural designing.

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