

IP 01 - SEGMENTATION

- Divide an object into independent parts.
- Make an object easy to disassemble.
- Increase the degree of fragmentation or segmentation.“ [p. 263]

Source: tetris – Teaching TRIZ at school

- use or create modular and dismountable equipment (e. g. quick-fit shelves, carts, workplaces)
- use or create equipment with a core and peripheral extensions (e. g. computer with separate monitor, mouse, etc. instead of integrated display)
- cut production lots into smaller lots – create small lot sizes (aspired optimal lot size: 1 piece)
- cut transportation lots into smaller lots – create small lot sizes (not bigger than the production lot)
- describe standard-work in detail
- divide problem-solving in distinct steps (e. g. plan-do-check-act (PDCA) or more detailed problem-solving processes like: problem description, gathering of data, target description, root-cause analysis, development of hypotheses and countermeasures, test of hypotheses and measures, implementation and standardization of measures or start of a new problem-solving process)

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IP 02 - EXTRACTION

- Extract the “disturbing” part or property from the object.
- Extract only the necessary part or property from an object.“ [p. 263]

Source: tetris – Teaching TRIZ at school

- separate non-value adding activities: isolate obvious waste and eliminate it
- separate non-value adding activities: isolate “necessary” waste and reduce it
- separate change-over tasks, that may be performed while machine is still or again running (external set-up) from change-over tasks that require machine holdup
- eliminate features of the product or service that are not desired by the customer
- eliminate or separate potential mistakes or errors

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IP 03 – LOCAL QUALITY

- Transition from homogenous to heterogeneous structure of an object or outside environment (action).
- Different parts of an object should carry out different functions.
- Each part of an object should be placed under conditions that are most favorable for its operation.“ [p. 263]

Source: tetris – Teaching TRIZ at school

- assign value adding and non-value adding tasks to different people (nurse surgeon principle)
- don't buy large general-purpose machines – instead buy one (or several) simple machines with a small range of application each
- use safety stock only at distinct points where needed: e. g. use in-process-kanban or supermarkets – don't use safety stocks in general

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IP 04 - ASYMMETRY

- Replace symmetrical form(s) with asymmetrical form(s).
- If an object is already asymmetrical, increase its degree of asymmetry.“ [p. 263]

Source: tetris – Teaching TRIZ at school

- assign value adding and non-value adding tasks to different people (nurse surgeon principle)
- design objects or processes that asymmetric, so they can't be confound with each other (e. g. USB-A- and USB-B plugs, different keys, symbols for visual controls)
- design objects or processes that asymmetric, so they can't be used in the wrong way (e. g. 3 pin power plugs, keys to use with locking cylinder)

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IP 05 – CONSOLIDATION (MERGING)

- Consolidate in space homogeneous objects, or objects destined for contiguous operations.
- Consolidate in time homogeneous or contiguous operations.“ [p. 263]

Source: tetris – Teaching TRIZ at school

- create team structures in such a way, that the team members have the same skills and tasks (but these may be widespread and interdisciplinary)
- place machines, equipment and workplaces in a way, that allows the flow of work pieces (or maybe the flow of information or people)
- design the material flow of the final assembly of a product as a flow with a takt; the takt time is given through the available time divided by the amount of the customer needs
- design the material flow of parts and components as a flow with a takt; the takt time is given through the available time divided by the amount of the customer needs
- place machines, equipment and workplaces in a way, that the flows of parts and components flow into the material flow of the product (or maybe the flow of information or the flow of people)

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IP 06 - UNIVERSALITY

- An object can perform several functions; therefore, other elements can be removed“[p. 263]

Source: tetris – Teaching TRIZ at school

- make small simple things multifunctional (e. g. a wrench with two different needed wrench widths at its ends)
- use standardized procedures (e. g. standardized problem solving process, standard operation procedures, standardized 3P- or improvement workshops, standardized shopfloor management, etc.)
- standardize efficient flows (material, information, people) in such a way, that different items can flow through in small lots (e. b. mixed model lines with one-piece-flow)

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IP 07 – NESTING (MATRIOSHKA)

- One object is placed inside another. That object is placed inside a third one. And so on ...
- An object passes through a cavity in another object.“ [p. 263]

Source: tetris – Teaching TRIZ at school

- provide all the things needed in specific standardized repositories at the point of application (e. g. different kinds of kitting in specific cases or standardized boxes or on/in the work piece itself)
- show outer contour of things to store the things within the contours (e. g. shadow boards, parking lots)
- integrate machines into manual work on assembly lines, if they fit the work sequence and the takt time (e. g. a simplified “mini“-milling machine right into an assembly line)
- use cavities in products during transport to store other products there to increase efficiency of transport

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IP 08 – COUNTERWEIGHT (ANTI-WEIGHT)

- Compensate for the weight of an object by combining it with another object that provides a lifting force.
- Compensate for the weight of an object with aerodynamic or hydrodynamic forces influenced by the outside environment.“ [p. 263]

Source: tetris – Teaching TRIZ at school

- use variable counterweights to create simple handling devices and manipulators (e. g. with pull of the rope)
- provide supporting functions by supporters to increase the value adding activities of operating people (e. g. team leaders and material handlers that create optimal working conditions for the value-adding work of the operators)

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IP 09 – PRIOR COUNTERACTION

- Preload countertension to an object to compensate excessive and undesirable stress.“ [p. 263]

Source: tetris – Teaching TRIZ at school

- use poka-yoke devices, that eliminate errors caused by mistake or carelessness
- use undestroyable standards, that prohibit wrong operation (e. g. it's not possible to place things on a skewed window board and a tied tool will not get lost)
- prepare working steps in such a way, that they don't have to be stopped while conduction (e. g. use checklists, perform functional tests, prepare toolsets)
- create compensatory conditions in advance (e. g. preparation of a cooling device for a tool that will eventually heat up later on)

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IP 10 – PRIOR ACTION (PRELIMINARY ACTION)

- Perform required changes to an object completely or partially in advance.
- Place objects in advance so that they can go into action immediately from the most convenient
- location.“ [p. 263]

Source: tetris – Teaching TRIZ at school

- provide the things (material, information) needed in the right amount, in the right moment for usage in schedule at the place of value creation (e. g. kitting of parts for assembly)
- locate materials, tools and information in such a way, that as less as possible motion and transportation are necessary (e. g. tool holders near the place of action, sort the tools in order of usage, preparation of screwdrivers regarding the needed torsional moment)
- create necessary working conditions in advance (e. g. pre-heating of a tool (that has to be hot for the operation) before insertion to the machine)

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IP 11 – CUSHION IN ADVANCE

- Compensate for the relatively low reliability of an object with emergency measures prepared in advance.“ [p. 264]

Source: tetris – Teaching TRIZ at school

- use poka-yoke devices, that eliminate errors caused by mistake or carelessness
- use poka-yoke or jidoka-devices to stop the process in case of a process error before this leads to defects of the product; more in detail: create mechanisms that check the process based on mechanical signals, countable data or perceptible sequences and that are able to stop the process if necessary by disabling it, discharging some parts or at least warning the operators
- use indestructible standards, that prohibit wrong operation (e. g. it's not possible to place things on a skewed window board and a tied tool will not get lost)

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IP 12 - EQUIPOTENTIALITY

- Change the condition of the work in such a way that it will not require lifting or lowering an object.“ [p. 264]

Source: tetris – Teaching TRIZ at school

- create consistent material flows (also information flows), so the transportation conditions of the materials will not change (e. g. placement of the object on a rollable table as well for processing it as for transportation between workplaces)
- create consistent and smooth velocity of procedures and things (e. g. moving lines, using takt, line balancing, leveled production)

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IP 13 – DO IT IN REVERSE

- Instead of the direct action dictated by a problem, implement an opposite action (i.e., cooling instead of heating).
- Make the moveable part of an object, or outside environment, stationary – and the stationary part moveable.
- Turn the object “upside down”.“ [p. 264]

Source: tetris – Teaching TRIZ at school

- make things (material, information) movable, instead of using conveyor mechanisms (e. g. a cart for each product vs. locating all parts on a belt conv.)
- fixate moveable equipment and make fixed equipment moveable (e. g. mount wheels on workbenches, bind tools on workbenches)
- use unidirectional lines – if not possible try to use bidirectional lines for manual working processes
- move the people and the material (e. g. in a chaku-chaku-line)
- move the people not the material (e. g. people-flow in a line with big heavy or not moveable work pieces)
- create standardized work sequences to create a leveled workload even if the work sequence for the operators differs to the sequence of process-steps that the product experiences (e. g. in a U-shaped cell with 2 operators and 8 stations one operator works at the stations 1,2,7,8 and the other works at the stations 3,4,5,6)

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IP 14 – SPHEROIDALITY (CURVATURE)

- Replace linear parts with curved parts, flat surfaces with spherical surfaces, and cube shapes with ball shapes.
- Use rollers, balls, spirals.
- Replace linear motion with rotational motion; utilize centrifugal force.“ [p. 264]

Source: tetris – Teaching TRIZ at school

- make things (material, information) moveable, instead of using conveyor mechanisms (e. g. a cart for each product instead of locating all parts on a belt conveyor)
- create material flows not only in straight lines – consider U-shapes or S-shapes

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IP 15 – DYNAMICS

- Characteristics of an object or outside environment, must be altered to provide optimal performance at each stage of an operation.
- If an object is immobile, make it mobile. Make it interchangeable.
- Divide an object into elements capable of changing their position relative to each other.“ [p. 264]

Source: tetris – Teaching TRIZ at school

- use systems for transport, replenishment and production control that are based on consumption of resources or things (e. g. Kanban circles, supermarkets)
- use the first-in-first-out principle
- make things (material, information) movable, instead of using conveyor mechanisms (e. g. a cart for each product instead of locating all parts on a belt conveyor)
- move the people and the material (e. g. in a chaku-chaku-line)
- move the people not the material (e. g. people-flow in a line with big heavy or not moveable workpieces)

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IP 16 – PARTIAL OR EXCESSIVE ACTION

- If it is difficult to obtain 100% of a desired effect, achieve more or less of the desired effect.“ [p. 264]

Source: tetris – Teaching TRIZ at school

- use pareto analysis and solve the most important problem first
- **ATTENTION: „excessive action“ is a very questionable term in the Lean lingo – it may be very hard to explain in a lean environment**
- a helpful example for the application of excessive action: to gauge a level coffee spoonful, first you take a pile of coffee on the spoon and then wipe off the abundant coffee (thanks for this suggestion to Svetlana Visnepolshi)

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IP 17 – TRANSITION INTO A NEW DIMENSION

- Transition one-dimensional movement or placement of objects into two-dimensional or three-dimensional, etc.
- Utilize multi-level composition of objects.
- Incline an object, or place it on its side.
- Utilize the opposite side of a given surface.
- Project optical lines onto neighboring areas or onto the reverse side of an object.“ [p. 264]

- use templates and masks to direct motions towards a specific way or curve (e. g. specific lifting carts to assemble objects into moving objects, mark three-dimensional objects for following operations like welding or cutting)

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IP 18 – MECHANICAL VIBRATION

- A. Utilize oscillation.
- B. If oscillation exists, increase its frequency to the ultrasonic.
- C. Use the frequency of resonance.
- D. Replace mechanical vibrations with piezo-vibrations.
- E. Use ultrasonic vibrations in conjunction with electromagnetic field.“ [p. 264]

- design transportation lots as small as possible without threatening the security of supply (e. g. calculation of kanban sizes)
- align all main processes with the takt time of the customer demand (e. g. available time divided by demand during this time) and conduct all activities clocked (e. g. use standardized work)
- align sub-processes and transportation with distinct frequencies (e. g. line cycle time, milk-run cycles)
- use working steps in repeating cycles

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IP 19 – PERIODIC ACTION

- Replace a continuous action with a periodic one (impulse).
- If an action is already periodic, change its frequency.
- Use pauses between impulses to provide additional action.“ [p. 264]

- change the line cycle time
- consider time needed for improvement and problem solving when calculating cycle times
- consider time needed for continuous improvement when balancing workload
- conduct change-over operations in flowlines periodically within the cycle time (e. g. change-over on station 1 at takt 1, station 2 at takt 2, etc.; so just one piece is lost because of change-over)

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IP 20 – CONTINUITY OF USEFUL ACTION

- Carry out an action without a break. All parts of the object should constantly operate at full capacity.
- Remove idle and intermediate motion.
- Replace “back-and-forth” motion with rotating one.“ [p. 265]

- realize a leveled production regarding amount and type of products (e. g. use Heijunka-Boards, line balancing, yamazumi)
- realize a consistent workload
- create flow of products, processes, information, people, materials and equipment

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IP 21 – RUSHING THROUGH (SKIPPING)

- Perform harmful and hazardous operations at a high speed, [p. 265]

- So far, there are no specific Lean-Operators for several Inventive Principles suggested. But these principles may also be used to solve problems in a lean environment – just by application in the usual way with ordinary operators or interpretations. And furthermore maybe in future further Lean-Operators can be added.

Source: tetris – Teaching TRIZ at school

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IP 22 – CONVERT HARM INTO BENEFIT

- Utilize harmful factors – especially environment – to obtain a positive effect
- Remove one harmful factor by combining it with another harmful factor
- Increase the degree of harmful action to such an extent that it ceases to be harmful [p. 265]

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IP 23 – FEEDBACK

- Introduce feedback.
- If feedback already exists change it.“ [p. 265]

- don't accept defective parts from the preceding process – give it back
- don't allow the following process to accept defective parts
- use feedback as essential part of learning and scientific approaches (e. g. create hypothesis, act and check the results for feedback whether the hypothesis could be true or false)
- use visual feedback (e. g. marked storage spaces, production figures, defect counter, failure signals, Andon displays, traffic signals)

Source: tetris – Teaching TRIZ at school

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IP 24 – MEDIATOR („INTERMEDIARY“)

- Use an intermediary object to transfer or carry out an action.
- Temporarily connect the original object to one that is easily removed.“ [p. 265]

- use carriers, shadow boards, templates and masks, carts with kitted materials
- use mediators that connect single parts to bigger units (e. g. system of small boxes that can be stacked to the size of a euro-pallet)
- prepare set-ups on special carts outside the machine with mediators
- use a combination of existing and not existing things (e. g. cardboard engineering, usage of mock-ups)

Source: tetris – Teaching TRIZ at school

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IP 25 – SELF-SERVICE

- An object must service itself and carry out supplementary and repair operations.
- Make use of waste material and energy.“ [p. 265]

Source: tetris – Teaching TRIZ at school

- use gravity for transportation (e. g. flow racks)
- use characteristics of the system to display information (e. g. stacks of boxes in front of a colored scale display the amount of pieces)
- use heat energy (e. g. heat of a machine used for drying)
- use in-process-kanban to integrate necessary waiting time into a line (e. g. defined number of parts in a flow line between painting and next operation to realize drying time)

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IP 26 – COPYING

- A simplified and inexpensive copy should be used in place of a fragile original or an object that is inconvenient to operate.
- If visible optical copy is used, replace it with infrared or ultraviolet copies.
- Replace an object (or system of objects) with their optical image. The image can then be reduced or enlarged.“ [p. 265]

Source: tetris – Teaching TRIZ at school

- simulate products or processes with cheap handmade mock-ups (e. g. cars made of pug or wood, products made of paper, workstations made of wood and cardboard)
- simulate surroundings by projection (e. g. taping shapes and contours, painting contours on the wall, using cordons)

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IP 27 – DISPOSE (CHEAP SHORT LIVING OBJECTS)

- Replace an expensive object with a cheap one, compromising other properties (i.e. longevity).“ [p. 265]

Source: tetris – Teaching TRIZ at school

- use or create modular and dismountable equipment (e. g. quick-fit shelves, carts, workplaces)
- use single-use masks and templates that can be revised simply

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IP 28 – REPLACEMENT OF MECHANICAL SYSTEM

- Replace a mechanical system with an optical, acoustical, thermal or olfactory system.
- Use an electric, magnetic and electromagnetic field to interact with an object.
- Replace fields that are:
 - Stationary with mobile
 - Fixed with changing in time
 - Random with structured
 - Use fields in conjunction with ferromagnetic particles.“ [p. 265]

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- use visual controls to display information (e. g. shadow boards, traffic lights, Andon displays)
- use acoustic signals to spread information (e. g. call for support, Andon-melodies, sirens)
- use mobile telecommunication technologies to realize Andon-functionality (e. g. a pager signal, if there is no audio-visual connection)

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IP 29 – PNEUMATIC OR HYDRAULIC CONSTRUCTIONS

- Replace solid parts of an object with gas or liquid. These parts can now use air or water for inflation, or use pneumatic or hydrostatic cushions.“ [p. 265]

Source: tetris – Teaching TIZ at school

- use pneumatic or hydraulic transportation technologies to move things without fixed conveyor technologies (e. g. moving heavy loads on air cushions)

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IP 30 – FLEXIBLE MEMBRANES OR THIN FILMS

- Replace customary constructions with flexible membranes or thin films.
- Isolate an object from its outside environment with flexible membranes or thin films.“ [p. 266]

Source: tetris – Teaching TIZ at school

- use thin films to wrap several parts together instead of using big boxes to realize standardized shapes and sizes

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IP 31 – POROUS MATERIAL

- Make an object porous, or use supplementary porous elements (inserts, covers, etc.).
- If an object is already porous, fill pores in advance with some substance.“ [p. 266]

Source: tetris – Teaching TIZ at school

- in a transferred sense: put some other work into a work system, when it can not be leveled – the additional work helps to balance the line (but: the additional work must be value-adding – maybe to another product)

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IP 32 – CHANGING THE COLOR (COLOR CHANGES)

- Change the color of an object or its environment.
- Change the degree of translucency of an object or its environment.
- Use color additives to observe an object or process which is difficult to see.
- If such additives are already used, employ luminescent traces or trace atoms.“ [p. 266]

Source: tetris – Teaching TIZ at school

- mark the location of things with colors (e. g. places for materials, defective parts, aisles, parking lots)
- mark the affiliation of things with colors (e. g. any tool, containment or fitting blue is dedicated to deal with water – any yellow one deals with oil; or each operator has its own colored tools)
- use traffic light colors to display the need or plenty of inventory (e. g. red, yellow, green)
- use colors to display different machine states (e. g. red=stopped, blue=needs maintenance)
- use colors to display deviations from the standard (e. g. pointer needle that reaches a red field of the visual display)

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IP 33 – HOMOGENEITY

- Objects interacting with the main object should be made out of the same material (or material with similar properties) as the main object.“ [p. 266]

Source: tetris – Teaching TRIZ at school

- consider the products or working units as ONE product family (one value-stream), that run through the same operation steps
- use the same part for different purposes to reduce complexity – use things that already exist

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IP 34 – REJECTING AND REGENERATING PARTS

- After completing its function, or becoming useless, an element of an object is rejected (discarded, dissolved, evaporated, etc.) or modified during its work process.
- Used-up parts of an object should be restored during its work.“ [p. 266]

Source: tetris – Teaching TRIZ at school

- create material flows not only in straight lines – consider U-shapes or S-shapes
- create machines that unload automatically after operation (e. g. hanedashi devices)

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IP 35 – TRANSFORMATION OF PROPERTIES

- Change the physical state of the system
- Change the concentration or density
- Change the degree of flexibility
- Change the temperature or volume

Source: tetris – Teaching TRIZ at school

- So far, there are no specific Lean-Operators for several Inventive Principles suggested. But these principles may also be used to solve problems in a lean environment – just by application in the usual way with ordinary operators or interpretations. And furthermore maybe in future further Lean-Operators can be added.

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IP 36 – PHASE TRANSITION

- Using the phenomena of phase change (i.e. a change in volume, the liberation or absorption of heat, etc.)

Source: tetris – Teaching TRIZ at school

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IP 37 – THERMAL EXPANSION

- Use expansion or contraction of material by changing its temperature
- Use various materials with different coefficients of thermal expansion

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IP 38 – ACCELERATED OXIDATION

- Make transition from one level of oxidation to the next higher level:
 - Ambient air to oxygenated
 - Oxygenated to oxygen
 - Oxygen to ionized oxygen
 - Ionized oxygen to ozoned oxygen
 - Ozoned oxygen to ozone
 - Ozoned to singlet oxygen

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IP 39 – INERT ENVIRONMENT (INERT ATMOSPHERE)

- Replace a normal environment with an inert one.
- Introduce a neutral substance or additives into an object.
- Carry out the process in a vacuum.“ [p. 266]

- in a transferred sense:
 - take away anything from the workspace that is not needed for the fulfillment of the task
 - reduce inventory to a minimum
 - conduct waste-detecting activities (e. g. muda-walk, stand in circle)

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IP 40 – COMPOSITE MATERIALS

- Replace homogeneous materials with composite ones.“ [p. 266]

- store things sorted by later consumption, not sorted by type (e. g. pallets with food for discounters contain mixed products, like different sauces on one pallet)
- produce different variants in one production line (e. g. mixed-model-line with one-piece-flow and heijunka)

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