The Overlap Between TRIZ and Lean

Amanda Bligh
IME 552: Lean Manufacturing Systems
University of Rhode Island

March 23, 2006

1 TRIZ

TRIZ (pronounced 'trees'), the Russian acronym for 'The Theory of Inventive Problem Solving, is a toolbox of techniques for problem solving. The basis for TRIZ was developed by Genrich Altshuller, a Soviet naval patent clerk, in the 1950s. As Altshuller was sorting through patents, he noticed that there are only so many ways that problems can be solved and that problems in different industries have been solved in similar ways. He sorted through thousands of patents and was able to find that one (or more) of 40 principles could explain each of the inventions he saw in these patents. He also noticed that each of these principles resolved a contradiction that had existed in the technologys development (i.e. an item has to be strong but light). Altshuller was able to find 38 possible attributes that could cause contradictions. From these insights, he developed a problem solving technique. The TRIZ problem solving methods consist of a number of different tools that can be used together or apart for problem solving and failure analysis.

Generally, the problem solving process in TRIZ is to take a specific problem, define it, generalize it by finding the contradictions and underlying principles, find examples of how others have solved the contradiction or utilized those principles, and finally, apply those general solutions to the particular problem. This process is similar to applying a math formula, such as the quadratic formula, to a specific situation: generalize the problem to use the formula, then take the generalized solution to apply to the particular problem.

1.1 Defining the Problem

Defining the problem is the most important and often the most difficult step, as there are numerous impediments. First, the situation is often obscured by jargon. Words that are commonly used within an industry, but arent used elsewhere can suffer from non-uniform definitions and can obscure assumptions about the problem or industry. For example, in the toy industry, the term 'play-pattern' is commonly used to describe how a child will play with a toy. This word can vary in meaning depending on the type of toy and the perspective: on an electronic toy it may mean the flow charts behind the electronics, the way the child interacts with it or how it is used when the electronics are not activated. To make sure that assumptions implicate in jargon (such as only a child will use this item) aren't obscuring the cause of the problem, jargon should be removed and replaced with what is actually intended by the use of the word or phrase.

Second, it can be difficult to find the actual problem that needs to be solved. While jargon can obscure some problems, false problems can obscure others. In some cases the wrong problem is addressed. For example: if the problem is that the cost is too high, is that due to excessive material, assembly method or other causes? High cost is not the cause of the problem, the reason for the high cost is: are the tolerances too tight, and causing expensive processes to be used, or is our factor of safety too large causing exotic materials to be used? The real problem must be found and examined, not the effect that is seen at the higher level.

In defining the problem, a list of all resources available is made. Resources include physical parts, movements, systems and manpower, but the complete list also includes fields, such as gravity and EMF. The breadth of the resource list defines the possible solution space for the problem, so it is important to include all resources, no matter how minor (excess heat) or common (air).

Additionally, at this stage it is important to identify the underlying contradiction that is causing the problem. For example, does item in question have to be both strong and light at the same time, or does the part have to be present, but its presence is causing a problem? The contradiction for the problem needs to be understood at the beginning in order to completely define the issue at hand.

Finally, a number of techniques that can help to define the problem and understand the context of the solution have been developed. One such technique is referred to as a '9-Box' or '9-Windows'. This technique places the system that is being worked with the context of its sub and super-systems and in the past and possible future embodiments of the system in question. The idea is to zoom out of the present context of the system and understand the broader context. Such a technique can bring resources and possibilities into play that were not recognized before. Included in the back of this packet is an example of a completed '9-Windows' exercise from [1].

An optional step at this point it to define ideal solution for the problem. If all the rules of physics could be ignored, how would the problem be solved? What is standing in the way of achieving that? Could the circumstances be changed? Are there additional resources that are creating the impediment to ideality? The ideal final result can differ based on the point of view from which it is determined: it can be thought of in terms of the consumer, manufacture, supplier, etc. The differences in the ideal can help to determine what areas of the design are of interest to all, or only to particular people. From this, an understanding of the situation that is causing the problem, what approaches can be taken to solve and where common interests lie can be gained.

1.2 Generalizing the Problem

The problem is generalized by selecting a particular TRIZ problem solving tool to use as a first approach. There are a number of tools to choose from based on the particular situation. Below is an incomplete list of possible TRIZ tools for use in generalizing the problem. Included here are the fundamental tools. There are others (substance-field analysis, trends of technical evolution) which are more complicated to use and beyond the scope of this introduction.

1.2.1 Separation Principles

A subset of Altshullers 40 principles are the separation principles. The separation principles are usually used first, as they can often quickly propose a solution. As the name states, these principles refer to separation of some quality. There are four separation principles: separations of parts and whole, separation in time, separation in space and separation based upon condition. The principles are meant to inspire solutions.

1. *Separation of Parts and Whole:* Can the actions/parts/systems be broken up into smaller parts? Can separate actions/parts/systems be combine into one whole?

2. *Separation in Time:* Can the actions/parts/systems that are causing the conflict be separated in time? Can one action happen before or after the other?

3. *Separation in Space:* Can the conflict be resolved by physically moving the actions/parts/systems? Can removing a separation in space combine actions/parts/systems and remove the conflict (combination of separation of parts and whole and space)?

4. *Separation on Condition:* Can the actions/parts/systems be treated/handled differently based on internal or external conditions?

1.2.2 40 Principles

The 40 Principles are based on the patterns of development and technology bases that Altshuller found from his patent analysis. These can be used less formally for brainstorming inspiration, or found from utilizing the contradiction table (below) to help inspire solutions. A list and definitions of the 40 Principles, summarized from [1], is attached to this package.

1.2.3 Contradiction Table

The contradiction table is a TRIZ tool that provides possible solutions for the contradiction that exists in the problem being solved. To use the contradiction table, the problem at hand needs to be defined in terms of one or more of the 38 contradictions that are listed in the first column and first row of the table. The desired attribute is found in the first column and the conflicting attribute is found the first row. Each attribute is then traced down or right to the intersection square. In this square are up to 4 numbers that correspond to the 40 principles that Altshuller found from examining patents.

These principles are intended to be used as starting points for inspiration in solving the problem at hand and resolving the afflicting conflict. The solver is by no means limited to using only those principles. The principles listed are given based on the frequency of solutions related to those principles resolving the particular confilict. Computer programs exist that help to inspire by presenting patents that show examples of the principles. A copy of the contradiction table is attached to this package that was included with [1].

1.2.4 Reverse TRIZ

The Reverse TRIZ technique is often used for failure analysis, but can also be used to discover potential problems. This technique asks the problem solver to look at the system that includes the failure and ask the question: If I were going to sabotage this system, how would I do it? The idea of this technique is to find the weak points in the system. For failure analysis, this can expose contradictions of system related to the failure that aren't obvious. With the contradictions defined, the separation or 40 principles can be used to help resolve the failure. In the design realm, Reverse TRIZ can be used to anticipate and discover problems that can occur within systems or products, as the worst-case can quickly be realized and evaluated.

1.2.5 Smart Little People

This TRIZ technique asks the problem solver to think of the site of the problem in terms of smart little people. If there were very tiny people at the site of the problem, what would they do to solve it? Would they hold up small boards to prevent contact? Would they jump up and down? Again, this technique is intended to get the problem solver to think about the situation in a different way. By focusing on the micro situation, a new perspective of on the problem can be gained. This technique can be used with the separation principles or the 40 principles once the conflict has been identified.

1.2.6 Ideal Final Result

Ideality can also be used as a problem solving tool. As explained above, this technique is to think about the perfect result to the problem at hand, disregarding physical and monetary limitations. The ideal final result can then be used back out ideas that have similar features to the perfect result.

1.3 Generating Solutions

The next step in the process, once a problem solving tool has been chosen is to generate possible solutions. In the outline offered at the beginning, this step includes finding the general solution and using the general solution to find a specific solution for the given problem. This is done by applying the tool to the defined problem, finding general solutions then using the general solutions to list specific solutions.

A general solution is a principle that is determined from the contradiction table (as described above), or selected from the separation principles. It could also be the initial ideal final result, or the description of what the smart little people would do. The next step is to make the jump from the general to the specific.

It is at this point that knowledge of many industries and technical areas are helpful. For example, if the tool being used is the contradiction table, the result of the contradiction table is a choice of up to four of the 40 Principles. Knowledge of other industries can help to discover comparable solutions in other industries. Knowing about the segmentation of tank treads, may lead to the application of a similar solution in a consumer product setting, if the contradiction table had pointed toward the principle of segmentation (there is software that automates this process and can suggest relevant patents to the principles that are being investigated).

For another example, if the tool used was the ideal final result, and it was determined that the system would work perfectly if it weren't for the presence of UV radiation, maybe the solution is that this system be only used in a shaded area or at night.

Though it still takes some creativity to determine the ultimate solution for a problem, the goal of TRIZ is to order how the problem is thought about to help arrive more quickly at the optimal solution. Like any other tool, the more often it is used, the better the user becomes at judging which solution path will be most effective.

2 Overlap Between TRIZ and Lean Ideas

TRIZ and lean thinking have many common points. Overall, they are both ways of improving the operation of a system. TRIZ focuses on individual elements to optimize, where lean takes in the entire system to find potential efficiencies. The similarities are not only on the system level. Many TRIZ elements have a lean counterpart.

Both TRIZ and lean take a substantial amount of time to define the problem. In TRIZ it is very important to understand all of the resources that can be used to solve a problem and to understand where the real problem lies. This can be done by the '9-Window', as described above, or by other methods. In lean, the goal is to understand the entire system and how materials and information move through it. To do this, the primary tool is the current state map. The current state map defines the system in lean terms much like the '9-Window' exercise defines the context for a TRIZ problem. Both are used as starting point for a complete understanding of the system.

Both TRIZ and lean have a desire to move beyond what is currently being understood as the truth. In TRIZ, the problem solver must uncover the assumptions that are made by the use of jargon and current problem definition. In lean, a common term is 'go and see'. This means that it is better when defining the system at hand to go and see how it works, not just assume that the information that has already been gathered is correct.

TRIZ and lean both look toward the future ideal. TRIZ uses the idea of the 'perfect' system to understand what is wrong with the current system and why ideality can't be implemented. Lean uses the future state map to write down a set of goals to aim for in the lean implementation. Through both systems, the goal is to reach a more ideal state than the current, whether it be a particular problem solution or a plant reorganization.

Finally, both TRIZ and lean look to optimize the use of available resources. In lean, the goal is to eliminate waste, as waste means there are inefficiencies and counter-productive actions in the system. In TRIZ often the problem solution utilizes a resource that had previously been seen as a nuisance or as waste. All of these overlapping elements speak to the use of TRIZ ideas in a lean implementation.

3 Using TRIZ in Lean

TRIZ can also be a useful addition to lean. TRIZ, as a problem solving technique, can be used within lean to find methods of accomplishing tasks that may not have otherwise been found. TRIZ lends itself well to finding solutions that utilize currently available resources that may otherwise be seen as waste ('muda' in lean). In addition, TRIZ's ideal final result could help in developing future state maps, by looking at a particular process and its role in the entire system and determining how ideality for both can be balanced. Finally, in creating the current state map, TRIZ's problem defining techniques, such as '9-Windows' and eliminating jargon could be very helpful, as in any problem situation there are numerous elements in the context and definition that are not adequately explored.

For example, TRIZ's '9-Window' exercise could help give context to a company's position in the market and help others understand just how important it is to work together with the 'super system' of distributors and the 'subsystem' of suppliers. Additionally, this exercise helps describe where the company has been and where it is going. This context could help greatly in developing a current state map as it could quickly give those not entirely familiar with it a snapshot of the company.

4 Conclusion

TRIZ is a set of problem solving tools that have been briefly and incompletely outlined above. The techniques listed, though basic, are very powerful and can quickly lead to inventive solutions to difficult problems. More information about TRIZ can be found in the books and websites listed in the references.

TRIZ and lean are both useful methods for developing optimized products or companies. While TRIZ tends to focus more often on smaller problems, lean is used more for systems level examination. Both, though can be used hand-in-hand for solving problems both in the macro and micro sense.

References

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A TRIZ 40 Principles

1. **Segmentation** Divide a system into separate parts or sections; Make a system easy to put together or take apart; Increase the amount of segmentation
2. **Taking Out** Where a system provides several functions of which one or more is not required (and may be harmful) at certain conditions, design the system so they are or can be taken out.
3. **Local Quality** Where an object or a system is uniform or homogenous, make it non-uniform; Change things around the system from uniform to non-uniform; Enable each part of a system to function in locally optimized conditions; Enable each part of a system or object to carry out different useful functions
4. **Asymmetry** Where an object or system is symmetrical or contains lines of symmetry, introduce asymmetries; Change the shape of an object or system to suit external asymmetries; If an object or system is already asymmetrical, increase the degree of asymmetry
5. **Merging** Physically join or merge identical or related objects, operations or functions; Join or merge objects, operations or functions so that they act together in time
6. **Universality** Make an object or system able to perform multiple functions, eliminating the need for other systems
7. **"Nested Doll"** Put one object inside another; Put several objects or systems inside others; Allow one object or system to pass through an appropriate hole in another
8. **Anti-Weight** Where the weight of an object or system causes problems, combine it with something that provides lift or use aerodynamic, hydrodynamic, buoyancy or other forces to provide lift
9. **Preliminary Anti-Action** Where an action contains both harmful and useful effects, precede the action with opposite or anti-actions to reduce or eliminate the harmful effects; Introduce stresses in an object to oppose known harmful working stresses later on
10. **Preliminary Action** Introduce a useful action into an object or system (fully or partially) before it is needed; Pre-arrange objects or systems such that they can come into action at the most convenient time and place
11. **Beforehand Cushioning** Introduce emergency backups to compensate for the potentially low reliability of an object (belt and suspenders)
12. **Equipotentiality** If an object or system requires or is exposed to tension or compression forces are eliminated or are balanced by the surrounding environment
13. **"The other way around"** Use an opposite action(s) used to solve the problem; make moveable objects fixed, and the fixed objects movable; Turn the object, system or process upside-down
14. **SpheroidalityCurvature** Turn straight edges or flat surfaces into curves; Use rollers, balls, spirals, domes; Switch between linear and rotary motion; Introduce or make use of centrifugal forces
15. **Dynamics** Allow a system or object to change to achieve optimal operation under different conditions; Split an object or system into parts capable of moving relative to each other; If an object or system is rigid or inflexible, make it movable or adaptable; Increase the amount of free motion
16. **Partial or Excessive Actions** If exactly the right amount of an action is hard to achieve, use slightly less or slightly more of the action to reduce or eliminate the problem.

17. **Another Dimension** If an object contains or mores in a straight line, consider use of dimensions or movement outside the line; consider use of dimensions or movement outside the current plane; Use a stacking arrangement of objects instead of a single level arrangement; Re-orient the object or system, lay it on its side; Use another side of a given object or system

18. **Mechanical Vibration** Cause an object to oscillate or vibrate; Increase the vibration frequency (ultrasonic); Make use of an object or systems resonant frequency; Use piezoelectric vibrators; Use combined field oscillations

19. **Periodic Action** Replace continuous actions with periodic or pulsating actions; If an action is already periodic, change the periodic magnitude or frequency to suit external requirements; Use gaps between actions to perform different useful actions

20. **Continuity of Useful Action** Make all parts of an object or system work at full load or optimum efficiency all the time; Eliminate all idle or non-productive actions or work;

21. **Skipping** Conduct an action a very high speed to eliminate harmful side effects

22. **"Blessing in Disguise"** Transform harmful objects or actions (particularly, the environment or surroundings) so that they deliver a positive effect; Add a 2nd harmful object or action to neutralized or eliminate the effect of an existing harmful object or action; Increase a harmful factor to such a level that it no longer causes harm

23. **Feedback** Introduce feedback to improve a process or action; Make current feedback adaptable to variations in operating requirements or conditions

24. **"Intermediary"** Introduce an intermediary between two objects, systems or actions; Introduce a temporary intermediately which disappears or can be easily removed after it has completed its function

25. **Self-Service** Enable an object or system to perform functions by itself or organize itself; Make use of waste resources energy or substances

26. **Copying** Use simple and inexpensive copies in place of expensive, possibly vulnerable objects or systems; Replace an object or action with an optical copy; Use infrared or ultraviolet wavelengths with optical copies

27. **Cheap Short-living Objects** Replace an expensive object or system with a multitude of inexpensive, short-life objects

28. **Mechanics Substitution / Another Sense** Replace an existing means with a means of making use of another sense (optical, acoustic, taste, touch or smell); Introduce electric, magnetic or electromagnetic fields to interact with an object or system; Change from static to movable, fixed to variable, and/or from unstructured to structured fields; Used fields in conjunction with field-activated objects or systems

29. **Pneumatics and Hydraulics** Use gases and liquids instead of solid parts or systems

30. **Flexible Shells and Thin Films** Incorporate flexible shells and thin films instead of solid structures; Isolate an object or system from a potentially harmful environment using flexible shells and thin films

31. **Porous Materials** Make and object porous or add porous elements; Add something useful into the pores

32. **Color Changes** Change the color or an object or its surroundings; Change the transparency of an object or its surroundings; In order to change the visibility or things, use colored additives or luminescent elements; Change the emissivity properties of an object subject to radiant heating

33. **Homogeneity** Make interaction objects from the same material (or material with similar properties)

34. **Discarding and Recovering** Make elements of an object or system that have fulfilled their functions disappear (dissolving, etc.) or appear to disappear; Restore consumable or degradable parts of an object or system during operation

35. **Parameter Changes** Change an objects physical state; Change concentration or consistency; Change the degree of flexibility; Change the temperature; Change the pressure; Change other parameters

36. **Phase Transitions** Make use of phenomena taking place during phase transitions (volume changes, heat loss, etc.)

37. **Thermal Expansion** Use thermal expansion or contraction of materials to achieve a useful result; Use multiple materials with different thermal expansion rates to achieve different useful effects

38. **Strong Oxidants** Replace atmospheric air with oxygen-enriched air; Use pure oxygen; Use ionizing radiation; Use ionized oxygen; Use ozone

39. **Inert Atmosphere** Replace a normal environment with an inert one; Add neutral parts, or inert elements to an object or system

40. **Composite Material** Change from uniform to composite (multiple) materials where each material is optimized to a particular functional requirement

B TRIZ Contradiction Table

Worsening Feature →

Improving Feature ↓

	Improving Feature	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
1	Weight of moving object		-	15 8 29 34	-	29 17 38 34	-	29 2 40 28	-	2 8 15 38	8 10 18 37	10 36 37 40	10 14 35 40	1 35 19 39
2	Weight of stationary object	-		-	10 1 29 35	-	35 30 13 2	-	5 35 14 2	-	8 10 19 35	13 29 10 18	13 10 29 14	26 39 1 40
3	Length of moving object	8 15 29 34	-		-	15 17 4	-	7 17 4 35	-	13 4 8	17 10 4	1 8 35	1 8 10 29	1 8 15 34
4	Length of stationary object		35 28 40 29	-		-	17 7 10 40	-	35 8 2 14	-	28 10	1 14 35	13 14 15 7	39 37 35
5	Area of moving object	2 17 29 4	-	14 15 18 4	-		-	7 14 17 4		29 30 4 34	19 30 35 2	10 15 36 28	5 34 29 4	11 2 13 39
6	Area of stationary object	-	30 2 14 18	-	26 7 9 39	-		-		-	1 18 35 36	10 15 36 37		2 38
7	Volume of moving object	2 26 29 40	-	1 7 4 35	-	1 7 4 17	-		-	29 4 38 34	15 35 36 37	6 35 36 37	1 15 29 4	28 10 1 39
8	Volume of stationary object	-	35 10 19 14	19 14	35 8 2 14	-		-		-	2 18 37	24 35	7 2 35	34 28 35 40
9	Speed	2 28 13 38	-	13 14 8	-	29 30 34	-	7 29 34	-		13 28 15 19	6 18 38 40	35 15 18 34	28 33 1 18
10	Force (Intensity)	8 1 37 18	18 13 1 28	17 19 9 36	28 10	19 10 15	1 18 36 37	15 9 12 37	2 36 18 37	13 28 15 12		18 21 11	10 35 40 34	35 10 21
11	Stress or pressure	10 36 37 40	13 29 10 18	35 10 36	35 1 14 16	10 15 36 28	10 15 36 37	6 35 10	35 24	6 35 36	36 35 21		35 4 15 10	35 33 2 40
12	Shape	8 10 29 40	15 10 26 3	29 34 5 4	13 14 10 7	5 34 4 10		14 4 15 22	7 2 35	35 15 34 18	35 10 37 40	34 15 10 14		33 1 18 4
13	Stability of the object's composition	21 35 2 39	26 39 1 40	13 15 1 28	37	2 11 13	39	28 10 19 39	34 28 35 40	33 15 28 18	10 35 21 16	2 35 40	22 1 18 4	
14	Strength	1 8 40 15	40 26 27 1	1 15 8 35	15 14 28 26	3 34 40 29	9 40 28	10 15 14 7	9 14 17 15	8 13 26 14	10 18 3 14	10 3 18 40	10 30 35 40	13 17 35
15	Duration of action by moving obejct	19 5 34 31	-	2 19 9	-	3 17 19	-	10 2 19 30	-	3 35 5	19 2 16	19 3 27	14 26 28 25	13 3 35
16	Duration of action by Stationary object	-	6 27 19 16	-	1 40 35	-		-	35 34 38	-				39 35 3 23
17	Temperature	36 22 6 38	22 35 32	15 19 9	15 19 9	3 35 39 18	35 38	34 39 40 18	35 6 4	2 28 36 30	35 10 3 21	35 39 19 2	14 22 19 32	1 35 32
18	Illumination Intensity	19 1 32	2 35 32	19 32 16		19 32 26		2 13 10		13 19 10	26 19 6		32 30	32 3 27
19	Use of energy by moving object	12 18 28 31	-	12 28	-	15 19 25	-	35 13 18	-	8 35	16 26 21 2	23 14 25	12 2 29	19 13 17 24
20	Use of energy by stationary object	-	19 9 6 27	-		-		-		-	36 37			27 4 29 18
21	Power	8 36 38 31	19 26 17 27	1 10 35 37		19 38	17 32 13 38	35 6 38	30 6 25	15 35 2	26 2 36 35	22 10 35	29 14 2 40	35 32 15 31
22	Loss of energy	15 6 19 28	19 6 18 9	7 2 6 13	6 38 7	15 26 17 30	17 7 30 18	7 18 23	7	16 35 38	36 38			14 2 39 6
23	Loss of Substance	35 6 23 40	35 6 22 32	14 29 10 39	10 28 24	35 2 10 31	10 18 39 31	1 29 30 36	3 39 18 31	10 13 28 38	14 15 18 40	3 36 37 10	29 35 3 5	2 14 30 40
24	Loss of Information	10 24 35	10 35 5	1 26	26	30 26	30 16		2 22	26 32				
25	Loss of Time	10 20 37 35	10 20 26 5	15 2 29	30 24 14 5	26 4 5 16	10 35 17 4	2 5 34 10	35 16 32 18		10 37 36 5	37 36 4	4 10 34 17	35 3 22 5
26	Quantity of Substance	35 6 18 31	27 26 18 35	29 35 14 18		15 14 29	2 18 40 4	15 20 29		35 29 34 28	35 14 3	10 36 14 3	35 14	15 2 17 40
27	Reliability	3 8 10 40	3 10 8 28	15 9 14 4	15 29 28 11	17 10 14 16	32 35 40 4	3 10 14 24	2 35 24	21 35 11 28	8 28 10 3	10 24 35 19	35 1 16 11	
28	Measurement Accuracy	32 35 26 28	28 35 25 26	28 26 5 16	32 28 3 16	26 28 32 3	26 28 32 3	32 13 6		28 13 32 24	32 2	6 28 32	6 28 32	32 35 13
29	Manufacturing Precision	28 32 13 18	28 35 27 9	10 28 29 37	2 32 10	28 33 29 32	2 29 18 36	32 23 2	25 10 35	10 28 32	28 19 34 36	3 35	32 30 40	30 18
30	Object affected harmful factors	22 21 27 39	2 22 13 24	17 1 39 4	1 18	22 1 33 28	27 2 39 35	22 23 37 35	34 39 19 27	21 22 35 28	13 35 39 18	22 2 37	22 1 3 35	35 24 30 18
31	Object-generated harmful factors	19 22 15 39	35 22 1 39	17 15 16 22		17 2 18 39	22 1 40	17 2 40	30 18 35 4	35 28 3 23	35 28 1 40	2 33 27 18	35 1	35 40 27 39
32	Ease of manufacture	28 29 15 16	1 27 36 13	1 29 13 17	15 17 27	13 1 26 12	16 40	13 29 1 40	35	35 13 8 1	35 12	35 19 1 37	1 28 13 27	1 13 11
33	Ease of operation	25 2 13 15	6 13 1 25	1 17 13 12		1 17 13 16	18 16 15 39	1 16 35 15	4 18 39 31	18 13 34	28 13 35	2 32 12	15 34 29 28	32 35 30
34	Ease of repair	2 27 35 11	2 27 35 11	1 28 10 25	3 18 31	15 13 32	16 25	25 2 35 11	1	34 9	1 11 10	13	1 13 2 4	2 35
35	Adaptability or versatility	1 6 15 8	19 15 29 16	35 1 29 2	1 35 16	35 30 29 7	15 16	15 35 29		35 10 14	15 17 20	35 16	15 37 1 8	35 30 14
36	Device complexity	26 30 34 36	2 26 35 39	1 19 26 24	26	14 1 13 16	6 36	34 26 6	1 16	34 10 28	26 16	19 1 35	29 13 28 15	2 22 17 19
37	Difficulty of detecting and measuring	27 26 28 13	6 13 28 1	16 17 26 24	26	2 13 18 17	2 39 30 16	29 1 4 16	2 18 26 31	3 4 16 35	30 28 40 19	35 36 37 32	27 13 1 39	11 22 39 30
38	Extent of automation	28 26 18 35	28 26 35 10	14 13 17 28	23	17 14 13		35 13 16		28 10	2 35	13 35	15 32 1 13	18 1
39	Productivity	35 26 24 37	28 27 15 3	18 4 28 38	30 7 14 26	10 26 34 31	10 35 17 7	2 6 34 10	35 37 10 2		28 15 10 36	10 37 14	14 10 34 40	35 3 22 39

	Improving Feature	14 Strength	15 Duration of action of a moving object	16 Duration of action of a stationary object	17 Temperature	18 Illumination Intensity	19 Use of energy by a moving object	20 Use of energy by a stationary object	21 Power	22 Loss of energy	23 Loss of substance	24 Loss of information	25 Loss of time	26 Quantity of substance
1	Weight of moving object	28 27 18 40	5 34 31 35	-	6 29 4 38	19 1 32	35 12 34 31	-	12 36 18 31	6 2 34 19	5 35 3 31	10 24 35	10 35 20 28	3 26 18 31
2	Weight of stationary object	28 2 10 27	-	2 27 19 6	28 19 32 22	19 32 35	-	18 19 28 1	15 19 18	18 19 28 15	5 8 13 30	10 15 35	10 20 35 26	19 6 18 26
3	Length of moving object	8 35 29 34	19	-	10 15 19	32	8 35 24	-	1 35	7 2 35 39	4 29 23 10	1 24	15 2 29	29 35
4	Length of stationary object	15 14 28 26	-	1 10 35	3 35 38 18	3 25	-		12 8	6 28	10 28 24 35	24 26	30 29 14	
5	Area of moving object	3 15 40 14	6 3	-	2 15 16	15 32 19 13	19 32	-	19 10 32 18	15 17 30 26	10 35 2 39	30 26	26 4	29 30 6 13
6	Area of stationary object	40	-	2 10 19 30	35 39 38		-		17 32	17 7 30	10 14 18 39	30 16	10 35 4 18	2 18 40 4
7	Volume of moving object	9 14 15 7	6 35 4	-	34 39 10 18	2 13 10	35	-	35 6 13 18	7 15 13 16	36 39 34 10	2 22	2 6 34 10	29 30 7
8	Volume of stationary object	9 14 17 15	-	35 34 38	35 6 4		-		30 6		10 39 35 34		35 16 32 18	35 3
9	Speed	8 3 26 14	3 19 35 5	-	28 30 36 2	10 13 19	8 15 35 38	-	19 35 38 2	14 20 19 35	10 13 28 38	13 26		10 19 29 38
10	Force (Intensity)	35 10 14 27	19 2		35 10 21	-	19 17 10	1 16 36 37	19 35 18 37	14 15	8 35 40 5		10 37 36	14 29 18 36
11	Stress or pressure	9 18 3 40	19 3 27		35 39 19 2	-	14 24 10 37		10 35 14	2 36 25	10 35 3 37		37 36 4	10 14 36
12	Shape	30 14 10 40	14 26 9 25		22 14 19 32	13 15 32	2 6 34 14		4 6 2	14	35 29 3 5		14 10 34 17	36 22
13	Stability of the object's composition	17 9 15	13 27 10 35	39 3 35 23	35 1 32	32 3 27 16	13 19	27 4 29 18	32 35 27 31	14 2 39 6	2 14 30 40		35 27	15 32 35
14	Strength		27 3 26		30 10 40	35 19	19 35 10	35	10 26 35 28	35	35 28 31 40		29 3 28 10	29 10 27
15	Duration of action by moving obejct	27 3 10		-	19 35 39	2 19 4 35	28 6 35 18		19 10 35 38		28 27 3 18	10	20 10 28 18	3 35 10 40
16	Duration of action by Stationary object		-		19 18 36 40		-		16		27 16 18 38	10	28 20 10 16	3 35 31
17	Temperature	10 30 22 40	19 13 39	19 18 36 40		32 30 21 16	19 15 3 17		2 14 17 25	21 17 35 38	21 36 29 31		35 28 21 18	3 17 30 39
18	Illumination Intensity	35 19	2 19 6		32 35 19		32 1 19	32 35 1 15	32	13 16 1 6	13 1	1 6	19 1 26 17	1 19
19	Use of energy by moving object	5 19 9 35	28 35 6 18	-	19 24 3 14	2 15 19		-	6 19 37 18	12 22 15 24	35 24 18 5		35 38 19 18	34 23 16 18
20	Use of energy by stationary object	35				19 2 35 32	-				28 27 18 31			3 35 31
21	Power	26 10 28	19 35 10 38	16	2 14 17 25	16 6 19	16 6 19 37			10 35 38	28 27 18 38	10 19	35 20 10 6	4 34 19
22	Loss of energy	26			19 38 7	1 13 32 15			3 38		35 27 2 37	19 10	10 18 32 7	7 18 25
23	Loss of Substance	35 28 31 40	28 27 3 18	27 16 18 38	21 36 39 31	1 6 13	35 18 24 5	28 27 12 31	28 27 18 38	35 27 2 31			15 18 35 10	6 3 10 24
24	Loss of Information		10	10		19			10 19	19 10			24 26 28 32	24 28 35
25	Loss of Time	29 3 28 18	20 10 28 18	28 20 10 16	35 29 21 18	1 19 26 17	35 38 19 18	1	35 20 10 6	10 5 18 32	35 18 10 39	24 26 28 32		35 38 18 16
26	Quantity of Substance	14 35 34 10	3 35 10 40	3 35 31	3 17 39		34 29 16 18	3 35 31	35	7 18 25	6 3 10 24	24 28 35	35 38 18 16	
27	Reliability	11 28	2 35 3 25	34 27 6 40	3 35 10	11 32 13	21 11 27 19	36 23	21 11 26 31	10 11 35	10 35 29 39	10 28	10 30 4	21 28 40 3
28	Measurement Accuracy	28 6 32	28 6 32	10 26 24	6 19 28 24	6 1 32	3 6 32		3 6 32	26 32 27	10 16 31 28		24 34 28 32	2 6 32
29	Manufacturing Precision	3 27	3 27 40		19 26	3 32	32 2		32 2	13 32 2	35 31 10 24		32 26 28 18	32 30
30	Object affected harmful factors	18 35 37 1	22 15 33 28	17 1 40 33	22 33 35 2	1 19 32 13	1 24 6 27	10 2 22 37	19 22 31 2	21 22 35 2	33 22 19 40	22 10 2	35 18 34	35 33 29 31
31	Object-generated harmful factors	15 35 22 2	15 22 33 31	21 39 16 22	22 35 2 24	19 24 39 32	2 35 6	19 18 22	2 35 18	21 35 2 22	10 1 34	10 21 29	1 22	3 24 39 1
32	Ease of manufacture	1 3 10 32	27 1 4	35 16	27 26 18	28 24 27 1	28 26 27 1	1 4	27 1 12 24	19 35	15 34 33	32 24 18 16	35 28 34 4	35 23 1 24
33	Ease of operation	32 40 3 28	29 3 8 25	1 16 25	26 27 13	13 17 1 24	1 13 24		35 34 2 10	2 19 13	28 32 2 24	4 10 27 22	4 28 10 34	12 35
34	Ease of repair	11 1 2 9	11 29 28 27	1	4 10	15 1 13	15 1 28 16		15 10 32 2	15 1 32 19	2 35 34 27		32 1 10 25	2 28 10 25
35	Adaptability or versatility	35 3 32 6	13 1 35	2 16	27 2 3 35	6 22 26 1	19 35 29 13		19 1 29	18 15 1	15 10 2 13		35 28	3 35 15
36	Device complexity	2 13 28	10 4 28 15		2 17 13	24 17 13	27 2 28 29		20 19 30 34	10 35 13 2	35 10 28 29		6 29	13 3 27 10
37	Difficulty of detecting and measuring	27 3 15 28	19 29 39 25	25 34 6 35	3 27 35 16	2 24 26	35 38	19 35 16	18 1 16 10	35 3 15 19	1 18 10 24	35 33 27 22	18 28 32 9	3 27 29 18
38	Extent of automation	25 13	6 9		26 2 19	8 32 19	2 32 13		28 2 27	23 28	35 10 18 5	35 33	24 28 35 30	35 13
39	Productivity	29 28 10 18	35 10 2 18	20 10 16 38	35 21 28 10	26 17 19 1	35 10 38 19	1	35 20 10	28 10 29 35	28 10 35 23	13 15 23		35 38

	Improving Feature	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
1	Weight of moving object	1 3 11 27	28 27 35 26	28 35 26 18	22 21 18 27	22 35 31 39	27 28 1 36	35 3 2 24	2 27 28 11	29 5 15 8	26 30 36 34	28 29 26 32	26 35 18 19	35 3 24 37
2	Weight of stationary object	10 28 8 3	18 26 28	10 1 35 17	2 19 22 37	35 22 1 39	28 1 9	6 13 1 32	2 27 28 11	19 15 29	1 10 26 39	25 28 17 15	2 26 35	1 28 15 35
3	Length of moving object	10 14 29 40	28 32 4	10 28 29 37	1 15 17 24	17 15	1 29 17	15 29 35 4	1 28 10	14 15 1 16	1 19 26 24	35 1 26 24	17 24 26 16	14 4 28 29
4	Length of stationary object	15 29 28	32 28 3	2 32 10	1 18		15 17 27	2 25	3	1 35	1 26	26		30 14 7 26
5	Area of moving object	29 9	26 28 32 3	2 32	22 33 28 1	17 2 18 39	13 1 26 24	15 17 13 16	15 13 10 1	15 30	14 1 13	2 36 26 18	14 30 28 23	10 26 34 2
6	Area of stationary object	32 35 40 4	26 28 32 3	2 29 18 36	27 2 39 35	22 1 40	40 16	16 4	16	15 16	1 18 36	2 35 30 18	23	10 15 17 7
7	Volume of moving object	14 1 40 11	26 28	25 28 2 16	22 21 27 35	17 2 40 1	29 1 40	15 13 30 12	10	15 29	26 1	29 26 4	35 34 16 24	10 6 2 34
8	Volume of stationary object	2 35 16		35 10 25	34 39 19 27	30 18 35 4	35		1		1 31	2 17 26		35 37 10 2
9	Speed	11 35 27 28	28 32 1 24	10 28 32 25	1 28 35 23	2 24 35 21	35 13 8 1	32 28 13 12	34 2 28 27	15 10 26	10 28 4 34	3 34 27 16	10 18	
10	Force (Intensity)	3 35 13 21	35 10 23 24	28 29 37 36	1 35 40 18	13 3 36 24	15 37 18 1	1 28 3 25	15 1 11	15 17 18 20	26 35 10 18	36 37 10 19	2 35	3 28 35 37
11	Stress or pressure	10 13 19 35	6 28 25	3 35	22 2 37	2 33 27 18	1 35 16	11	2	35	19 1 35	2 36 37	35 24	10 14 35 37
12	Shape	10 40 16	28 32 1	32 30 40	22 1 2 35	35 1	17 32 1 28	32 15 26	2 13 1	1 15 29	16 29 1 28	15 13 39	15 1 32	17 26 34 10
13	Stability of the object's composition		13	18	35 24 30 18	35 40 27 39	35 19	32 35 30	2 35 10 16	35 30 34 2	2 35 22 26	35 22 39 23	1 8 35	23 35 40 3
14	Strength	11 3	3 27 16	3 27	18 35 37 1	15 35 22 2	11 3 10 32	32 40 25 2	27 11 3	15 3 32	2 13 15 18	27 3 15 40	15	29 35 10 14
15	Duration of action by moving obejct	11 2 13	3	3 27 16 40	22 15 33 28	21 39 16 22	27 1 4	12 27	29 10 27	1 35 13	10 4 29 15	19 29 39 35	6 10	35 17 14 19
16	Duration of action by Stationary object	34 27 6 40	10 26 24		17 1 40 33	22	35 10	1	1	2		25 34 6 35	1	20 10 16 38
17	Temperature	19 35 3 10	32 19 24	24	22 33 35 2	22 35 2 24	26 27	26 27	4 10 16	2 18 27	2 17 16	3 27 35 31	26 2 19 16	15 28 35
18	Illumination Intensity		11 15 32	3 32	15 19	35 19 32 39	19 35 28 26	28 26 19	15 17 13 16	15 1 19	6 32 13	32 15	2 26 10	2 25 16
19	Use of energy by moving object	19 21 11 27	3 1 32		1 35 6 27	2 35 6	28 26 30	19 35	1 15 17 28	15 17 13 16	2 29 27 28	35 38	32 2	12 28 35
20	Use of energy by stationary object	10 36 23			10 2 22 37	19 22 18	1 4					19 35 16 25		1 6
21	Power	19 24 26 31	32 15 2	32 2	19 22 31 2	18 2 35	26 10 34	26 35 10	35 2 10 34	19 17 34	20 19 30 34	19 35 16	28 2 17	28 35 34
22	Loss of energy	11 10 35	32		21 22 35 2	21 35 2 22		35 32 1	2 19		7 23	35 3 15 23	2	28 10 29 35
23	Loss of Substance	10 29 39 35	16 34 31 28	35 10 24 31	33 22 30 40	10 1 34 29	15 34 33	32 28 2 24	2 35 34 27	15 10 2	35 10 28 24	35 18 10 13	35 10 18	28 35 10 23
24	Loss of Information	10 28 23			22 10 1	10 21 22	32	27 22				35 33	35	13 23 15
25	Loss of Time	10 30 4	24 34 28 32	24 26 28 18	35 18 34	35 22 18 39	35 28 34 4	4 28 10 34	32 10 1	35 28	6 29	18 28 32 10	24 28 35 30	
26	Quantity of Substance	18 3 28 40	13 2 28	33 30	35 33 29 31	3 35 40 39	29 1 35 27	35 29 25 10	2 32 10 25	15 3 29	3 13 27 10	3 27 29 18	8 35	13 29 3 27
27	Reliability		32 3 11 23	11 32 1	27 35 2 40	35 2 40 26		27 17 40	1 11	13 35 8 24	13 35 1	27 40 28	11 13 27	1 35 29 38
28	Measurement Accuracy	5 11 1 23			28 24 22 26	3 33 39 10	6 35 25 18	1 13 17 34	1 32 13 11	13 35 2	27 35 10 34	26 24 32 28	28 2 10 34	10 34 28 32
29	Manufacturing Precision	11 32 1			26 28 10 36	4 17 34 26		1 32 35 23	25 10		26 2 18		26 28 18 23	10 18 32 39
30	Object affected harmful factors	27 34 2 40	28 33 23 26	26 28 10 18			24 35 2	2 25 28 39	35 10 2	35 11 22 31	22 19 29 40	22 19 29 40	33 3 34	22 35 13 24
31	Object-generated harmful factors	24 2 40 39	3 33 26	4 17 34 26							19 1 31	2 21 27 1	2	22 35 18 39
32	Ease of manufacture		1 35 12 18		24 2			2 5 13 16	35 1 11 9	2 13 15	27 26 1	6 28 11 1	8 28 1	35 10 28 1
33	Ease of operation	17 27 8 40	25 13 2 34	1 32 35 23	2 25 28 39		2 5 12		12 26 1 32	15 34 1 16	32 26 12 17		1 34 12 3	15 1 28
34	Ease of repair	11 10 1 16	10 2 13	25 10	35 10 2 16		1 35 11 10	1 12 26 15		7 1 4 16	35 1 13 11		34 35 7 13	1 32 10
35	Adaptability or versatility	35 13 8 24	35 5 1 10		35 11 32 31		1 13 31	15 34 1 16	1 16 7 4		15 29 37 28	1	27 34 35	35 28 6 37
36	Device complexity	13 35 1	2 26 10 34	26 24 32	22 19 29 40	19 1	27 26 1 13	27 9 26 24	1 13	29 15 28 37		15 10 37 28	15 1 24	12 17 28
37	Difficulty of detecting and measuring	27 40 28 8	26 24 32 28		22 19 29 28	2 21	5 28 11 29	2 5	12 26	1 15	15 10 37 28		34 21	35 18
38	Extent of automation	11 27 32	28 26 10 34	28 26 18 23	2 33	2	1 26 13	1 12 34 3	1 35 13	27 4 1 35	15 24 10	34 27 25		5 12 35 26
39	Productivity	1 35 10 38	1 10 34 28	18 10 32 1	22 35 13 24	35 22 18 39	35 28 2 24	1 28 7 10	1 32 10 25	1 35 28 37	12 17 28 24	35 18 27 2	5 12 35 26	

HANDS•ON SYSTEMATIC INNOVATION

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40 Principles	
1	Segmentation
2	Taking Out
3	Local Quality
4	Asymmetry
5	Merging
6	Universality
7	"Nested Doll"
8	Anti-Weight
9	Preliminary Anti-Action
10	Preliminary Action
11	Beforehand Cushioning
12	Equipotentiality
13	"The other way round"
14	Spheroidality - Curvature
15	Dynamics
16	Partial or Excessive Actions
17	Another Dimension
18	Mechanical Vibration
19	Periodic Action
20	Continuity of Useful Action
21	Skipping
22	"Blessing in Disguise"
23	Feedback
24	"Intermediary"
25	Self-Service
26	Copying
27	Cheap Short-living Objects
28	Mechanics Substitution
29	Pneumatics and Hydraulics
30	Flexible shells and thin films
31	Porous Materials
32	Colour Changes
33	Homogeneity
34	Discarding and Recovering
35	Parameter Changes
36	Phase Transitions
37	Thermal Expansion
38	Strong Oxidants
39	Inert Atmosphere
40	Composite Materials

C 9-Windows Example

	Past *Before 'writing' begins*	Present *Person writing*	Future *After writing has finished*
Super System	pen display in shop, user preparing to write	user, paper desk, chair, light, environment	storage location, wear effects of environment
System *the pen*	assemble pack/deliver, store, prepare	pen being used to write	storing effect refilling wear factors, disposal
Subsystem	manufacture of individual components	component parts, ink flowing through nib	re-usability, recycleability of component parts