MODULE 3

Theory of Inventive Problem Solving (TRIZ)

Atila Ertas
Utku Gulbulak

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MODULE 3

Theory of Inventive Problem Solving (TRIZ)

Inventing is the resolution of technical contradictions.

Genrich Altshuller

3.1 Introduction

Theory of Inventive Problem Solving (TRIZ) developed by G.S. Altshuller and his colleagues in Russia between 1946 and 1985 is a well-known effective methodology to solve complex problems. It is a problem-solving methodology developed on the assessment of the repetitions of problems and solutions using logic, data, and research. TRIZ represents the output of over 2000 person-years worth of research into not just patents, but well-defined successful problem solutions from all areas of human work.[1] The number of Triz practitioners has grown 40% per year since 2007. Today many Fortune 500 companies successfully use the TRIZ methodology in at least 50 countries.[2]

"The Russian engineer and scientist Genrikh Altshuller studied thousands of patents and noticed certain patterns. From these patterns, he discovered that the evolution of a technical system is not a random process, but is governed by certain objective laws. These laws can be used to consciously develop a system along its path of technical evolution - by determining and implementing innovations."[2]

After Altshuller evaluated hundreds of thousands of patents to determine the patterns that predict innovative solutions to problems, he found that:[3]

(a) 99.7 percent of inventions were made using known methods of solution,

(b) only 0.3 percent of solutions were disruptive, and

(d) the innovation process can be systematically organized.

[1]Salamatov, Y., (1999). TRIZ: The Right Solution At The Right Time. Insytec BV, The Netherlands, 1999.
[2]The Altshuller Institute for TRIZ Studies. https://www.aitriz.org/triz, accessed July 20, 2020.
[3]Valeri Souchkov, (2017). Accelerate Innovation with TRIZ, http://www.xtriz.com/publications/Accelerate InnovationWithTRIZ.pdf, accessed July 15, 2020.

The main findings of systematic innovation are:[4]

1. "that the same problems and solutions appear again and again across different industries, but that most organizations tend to re-invent the wheel rather than look outside their own experiences or the experiences of their direct competitors.
2. that the most powerful solutions are the ones that successfully eliminate the compromises and trade-offs conventionally viewed as inherent in systems.
3. that there are only a small number of possible strategies for overcoming such contradictions.
4. that the most powerful solutions also make maximum use of resources. Most organizations are highly inclined to solve problems by adding things rather than making the current things work more effectively or transforming the things viewed as harmful into something useful.
5. that technology evolution trends follow highly predictable paths."

TRIZ transforms problems from the specific to the generic by assessing the current challenges with 40 different inventive principles. Altshuller and his colleagues who developed TRIZ found that:[5]

- Problems and solutions repeat across industries and sciences.
- Patterns of technical evolution repeat across industries and sciences.
- Innovations used scientific effects outside the field where they were developed.

Jumping to a solution for problem-solving is easy and often necessary. However, it just happens to be bad for product development. Even though we are aware that designers should avoid jumping to a problem solution, we still find it very hard to stop that very human desire of trying to figure out a solution as soon as possible. One of the important principles of TRIZ is, that instead of quickly jumping to a solution, TRIZ proposes to analyze a problem, build its model, and apply a relevant pattern of a solution from the TRIZ databases to discover possible solution directions.

Benefits of TRIZ are:[6]

- TRIZ problem solving based on fixed repeatable algorithm
- TRIZ accelerates the speed of system development and evolution.
- TRIZ reduces the number of trials and errors to save money
- TRIZ helps model problems that are not well defined into a specific problem that can be solved by any engineer.
- TRIZ allows design teams to find examples of how people have solved similar problems in the past. In other words, somebody, somewhere, has already solved your problem or one related to it. Creativity means finding that solution and altering it to your problem.

[4] TRIZ Journal. https://triz-journal.com/what-is-triz/, accessed July 17, 2020.
[5] http//www.triz-journal.com/whatistriz.htm, accessed August 20, 2015.
[6] The Altshuller Institute for TRIZ Studies. https://www.aitriz.org/triz/14-triz/triz/610-benefits#: :text= TRIZ%20increases%20the%20speed%20of,be%20solved%20by%20any%20engineer, accessed July 18, 2020.

As seen from Figure 3.1,[7] TRIZ not only reduces the number of trial and error iterations by avoiding much of the solution set and getting to the solution faster but also provides an exhaustive set of potential solution concepts compared with the conventional methods.

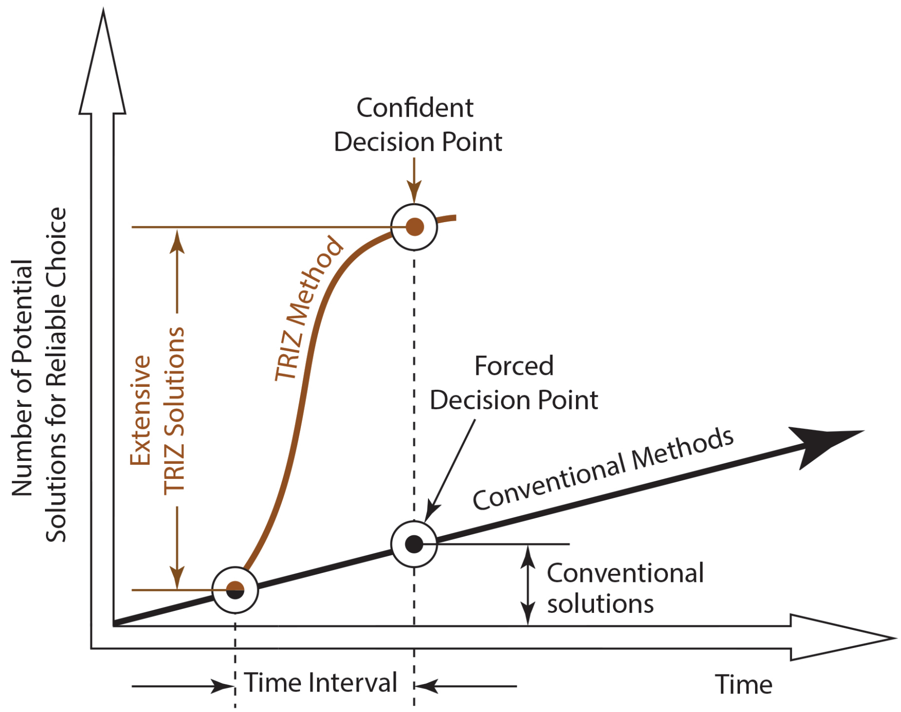


Figure 3.1: Impact of TRIZ on an organization (adapted from reference 7).

3.2 TRIZ Problem Solving Process

Figure 3.2 shows the process of TRIZ problem-solving.[8] A conventional approach for solving problems is to consider directly a specific problem to find a specific solution. However, in some cases, this approach may not work due to contradictions or conflicts among the characteristics of the problem which prevent the appropriate solution to generate. TRIZ's problem-solving process is different from the conventional methods of problem-solving. The basic approach of TRIZ is that in most cases the problem we are trying to solve now has already been solved by somebody in a different situation.

As seen from Figure 3.2, the TRIZ problem-solving process starts with identifying a specific problem with main functions such as the main functions of an aircraft including power, speed, weight, drag force, etc. that problem in hand is seeking to achieve.

[7]Recreated from Glenn Research Center at Lewis Field, NASA
[8]Ertas, A. (2018). Transdisciplinary Engineering Design Process. John Wiley and Sons, Inc.

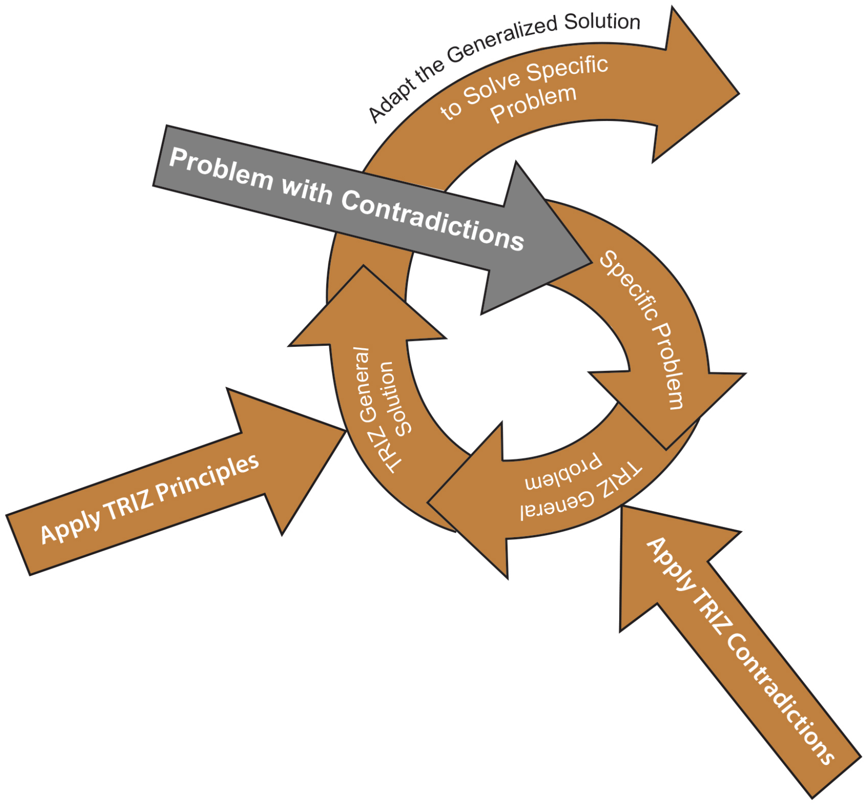


Figure 3.2: TRIZ problem solving process (adapted from reference 7).

The next step is to use the main functions, and establish contradictions in your specific problem. In other words, to decide what is getting better (good) and what is getting worse (bad).

The following step is to convert the specific problem into a TRIZ general problem – develop contradictions – identify the negative effect with a "worsening feature" in the Contradiction Matrix (Tables 3.1 through Table 1.6). Then identify positive effects with an "improving feature" in the Contradiction Matrix.

For example, increasing the strength of an aircraft's structural parts (improving feature) can result in increasing the weight (worsening feature) of the aircraft. There is a contradiction between these two pairs of the 39 TRIZ contradiction parameters: one gets better while the other gets worse. In TRIZ, there are 39 contradictions that have been identified to help us to solve the problem into consideration. TRIZ contradictions are listed in Table 3.1 through Table 3.6. An explanation of the 39 parameters of the contradiction matrix is given in Table 3.7.

Finally, using TRIZ inventive principles (see Table 3.8) corresponding to TRIZ contradictions, a TRIZ general solution can be found.

3.2.1 Contradictions

A contradiction is a situation of two parameters in opposition to one another. There are three kinds of contradictions in TRIZ: administrative, technical, and physical contradictions.

Administrative contradiction: tells a desire to improve a characteristic of a system without having a promising focus of solution – it is temporary, has no heuristic value, and stays at the surface of the problem.

Technical Contradiction: *Technical contradictions* are the typical engineering "trade-offs." When something gets better, something else is affected and gets worse – an attempt to improve one engineering parameter results in the worsening of another parameter. The following are some examples of trade-offs:

- The part products get stronger (good) but the weight increases (bad).
- Vehicles can be built to run faster (good) but the fuel efficiency decreases (bad).
- To have a nice dinner at a fancy restaurant (good) but the cost will be very high (bad).
- Deep-fried food is delicious to us because of the high energy and calorie level (good) but it increases cholesterol level (bad).
- Having fast aircraft cruising speed (good) can decrease the maximum lift/load capacity (bad).

Physical Contradiction: Technical contradictions occur between two parameters whereas a *physical contradiction* occurs when there is a conflict within a parameter itself. For example, if we use a long regular magnetic tool to pick up objects as shown in Figure 3.3(a), it may not be handy to carry. If we use a shorter magnetic tool for the same reason it may not be long enough to reach. In this case, the length of the tool is a parameter that creates a contradiction within a parameter (length) itself. The length of the magnetic tool should be long enough to reach but it should be short enough to easily carry – in this problem length is the physical contradiction. There are several ways of solving this contradiction. For example, if we use a telescopic magnetic tool to pick up various objects as shown in Figure 3.3(b), it is short enough to carry easily, and if we extend it will be long enough to reach.[9]

[9] Adapted from reference 8.

Figure 3.3: Magnetic pickup tool: (a) regular, (b) telescopic.

EXAMPLE 3.1

A new material for aircraft structural parts needed.The design of an aircraft takes into consideration a variety of factors. One of the most important ones is the strength-to-weight ratio of the aircraft's structural parts. The strength/weight conflict plays an important role in the design of aircraft structural parts. Use TRIZ analysis to resolve the conflict that will improve the strength/weight ratio.

ANALYSIS OF STATEMENT

Aircraft structural parts should be strong, but not heavy.

STEP 1:
Identify the contradiction(s)

- Strength (improves) versus
- Weight (worsens)

STEP 2:
Check Tables 3.1 through Table 3.6 and identify the improving and worsening features.

- Strength – #14
- Weight – #1

EXAMPLE 3.1 (continued)

STEP 3:
Identify which are improving features and which are worsening features and identify which principles can be used for this problem (see Figure 3.4).

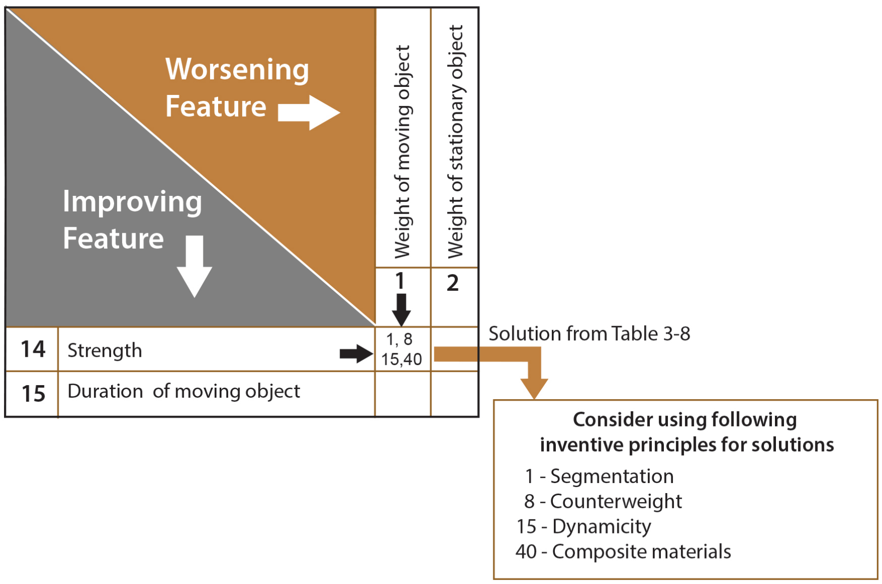


Figure 3.4: Identifying improving and worsening features.

STEP 4:
The intersection of Column 2 and Row 14 provides the following principles (see Table 3.8):

1 - Segmentation
8 - Counterweight
15 - Dynamicity
40 - Composite materials

STEP 5: Next step is to think which principle is useful to solve our problem. Principle 40 (composite material) is the most useful one for our problem (see TRIZ tool: http://www.rb-tdinstitute.org/index.php/blog-2/infinite-12):

3.2.2 TRIZ Separation of Principles

TRIZ Separation Principles is used to solve physical contradictions or when other ideation techniques are unsuccessful in resolving them. Separation removes the physical contradiction within a parameter and allows each requirement to be satisfied. For example, we require water in our house to be "cold" and "hot" for different functions. These two conflicting requirements within the parameter of "water" can be resolved by using the separation of principles. Separation of Principles is the more powerful and effective solution principle and tool among the broad category of TRIZ Principles.[10] There is four separations of principles to resolve physical contradiction:

1. Separation in time
2. Separation in space
3. Separation between the parts (components) and the whole (system)
4. Separation upon condition

1. Separation of Conflicting Properties in Time: Changing a property, response, and behavior vs. time. For example, by changing the cargo ship propeller blades to the optimal pitch in time, higher efficiency can be obtained, thus saving fuel (see Figure 3.5).

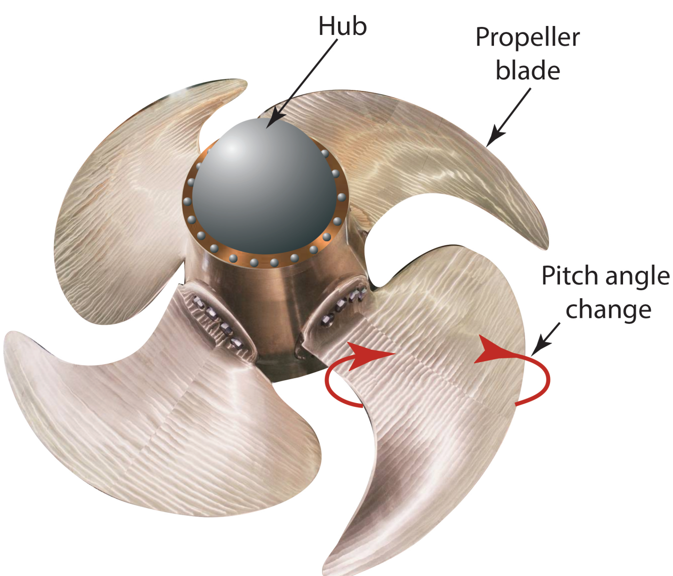


Figure 3.5: Controllable pitch propeller.

The rotational speed of the main engine is the only operational variable for fixed pitch propellers. If you would like to run the ship in a forwarding and astern direction you have to

[10]Hipple, J. (1999). The Use of TRIZ Separation Principles to Resolve the Contradictions of Innovation Practices in Organizations. *The Triz Journal,* https://triz-journal.com/use-triz-separation-principles-resolve-contradictions-innovation-practices-organizations/, accessed July 19, 2020.

stop the engine and change the engine's rotational direction. This will cause a waste of energy. Also, if you want to change the speed of the ship, you have to change the RPM of the engine – the speed of the ship will be handled from the navigation bridge and the marine engineer will be overwhelmed in order to change the ship's speed. So, how we can overcome the problems related to the fixed pitch propellers mentioned.

Applying separation in time results in an inventive solution of controllable pitch propellers. Changing the pitch of the propeller in time will run the ship in forwarding and astern directions both, without the change of engine rotational direction. Changing the pitch of the propeller in time determines the amount of thrust generated by the propeller – thus changing the speed of the ship. With this design approach, the weight of the engine and propulsion machinery is reduced considerably.

From Table 3.8, TRIZ principles most applicable to "separation in time" are: 9, 10, 11, 12, 15, 16, 18, 19, 20, 21, 35, 36, 37, 38, and 39.

2. Separation of Conflicting Properties in Space: Changing a property, response, or behavior based on a special location. For example, As shown in Figure 3.6, the knee brace is used after a knee injury to provide support while the knee injury is healing. They are designed to limit movement of the knee while it is healing after an injury or surgery. However, certain conditions will cause the kneecap to track improperly, causing pain in other locations. The pain is present in one place (around the knee joint) and absents in another place. The solution is having a small hole as shown in Figure 3.6 to support the kneecap. The hole in the brace will separate the space and cover the kneecap and help to keep it on track.

From Table 3.8, TRIZ principles most applicable to "separation in space" are: 1, 3, 4, 5, 7, 8, 13, 14, 15, 16, 17, 26, 27, 30, 31, and 32.

Figure 3.6: Knee brace.

3. The separation between the Parts and the Whole: Changing a property, response, and behavior to make it different at the component or system level. In other words, exist at the system level but does not exist at the component level (or vice versa). For example, plastic body fillers and hardeners showed in Figure 3.7 are liquids, but when you mixed them combination became solid.

From Table 3.8, TRIZ principles most applicable to "between parts and the whole" are: 2, 3, 6, 7, 24, 26, 27, 33, 34, and 40.

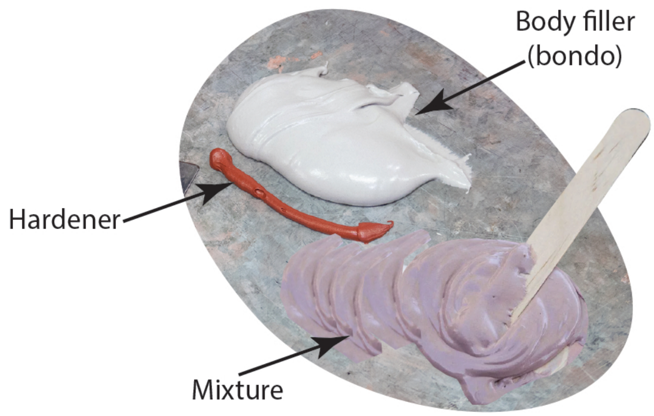


Figure 3.7: Mixing body filler and hardener.

4. Separation upon Condition: Changing the property, response, or behavior on condition. Properties can be high under one condition and low under another condition. A good example of this case is transitions lenses with a light-sensitive photochromic coating as shown in Figure 3.8. The lenses are light or dark changing the conditions of UV radiation present.

From Table 3.8, TRIZ principles most applicable to "separation of conditions" are: 6, 15, 16, 18, 19, 22, 28, 29, and 32.

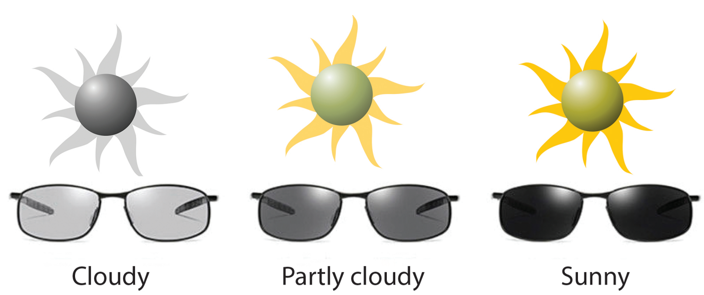


Figure 3.8: Light-sensitive photochromic coating lenses.

3.2.3 Ideality

The ideality approach is one of the most powerful fundamental TRIZ concepts, which is defined as the sum of the useful functions/effects in a system divided by the harmful functions/effects in a system. In other words, ideality is the ratio between all the good things you want (benefits) and any negative aspect (costs and harms). In the equation, ideality can be written as:

$$\begin{aligned} \text{Ideality} &= \frac{\sum \text{Useful Functions or Effects}}{\sum \text{Harmful Functions or Effects}} \\ &= \frac{\sum \text{Benefits}}{\sum \text{Costs} + \sum \text{Harms}} \end{aligned} \tag{3.1}$$

In Eq 3.1, benefits are all the useful functions/effects, harms are all the harmful functions/effects, and costs are all the inputs necessary to achieve the system functionality such as money, resources, time, manpower, energy etc.

All systems include useful and harmful functions. According to ideality, the ideal state of the system is where all its functions are achieved without creating harmful effects. The term "useful" refers to features or properties of a system that maximize satisfaction and minimize the unpleasant occurrence – this makes customers happy. But all of this comes with a cost. The term "harmful" refers to functions that include expense, noise, inefficient energy use, resources required, etc. Let's consider the following ideality example.

EXAMPLE 3.2

Ideality Example: Oil industry and refineries. The domestic petroleum industry in the U.S. began in 1859 and changed America's economy, standard of living, and culture. Now, petroleum's current status became the key component of politics, society, and technology. After oil discovery, the 19th century was the beginning of rapid industrialization. The iron and steel industry produced new materials for construction, the railroads linked the country and the discovery of oil provided an opportunity for a new source of fuel.[a]

ANALYSIS

Benefits of the Oil Industry and refineries (useful function):

EXAMPLE 3.2 (continued)

ANALYSIS

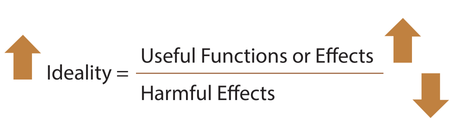
Benefits of the Oil Industry and refineries (useful function):

- Impact on rapid industrialization.
- High-value products such as gasoline, diesel fuel, and jet fuel.
- Refineries produce a wide variety of different products such as gasoline, diesel fuel, jet fuel, etc. By-products from oil refining include the production of plastics and chemicals, different kind of lubricants, waxes, tars, and asphalts.
- It is the world's most important source of energy.
- Oil products support modern society, by providing energy to the power industry and supplying fuel for vehicles and airplanes to transport goods and people all over the world. And many others.

But, these benefits come at a cost. The costs involved with the harmful functions. They are:

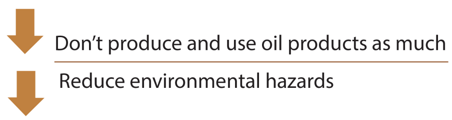
- Costs (workers)
  - Explosions
  - Exposure to gas
  - Exposure to chemicals
  - Burns
- Costs (society)
  - Environmental hazards (potential environmental hazards related with refineries have began increased concern for societies in close proximity to them.)
  - Air pollution hazards
  - Water pollution hazards
  - Soil pollution hazards

Now, we can define invention as:
Invention is anything that improves ideality and resolves contradictions. in other words, as seen from the below figure, improving the useful functions or effects and reducing the harmful effects improves the ideality. The goal is to optimize ideality without creating harmful effects.

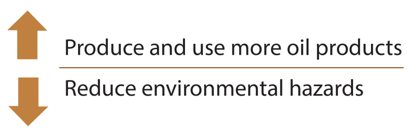


EXAMPLE 3.2 (continued)

Now consider inventing a better and environmentally friendly refinery. For this example, assume the useful function of providing energy against the harmful function of environmental hazards. As shown in the below figure, we can think that environmental hazards can be reduced by not producing and using oil products as much. But, this process doesn't invent anything because it doesn't improve ideality – that is nothing but give and take (compromise solutions).



However, as seen below figure, if we say, we can reduce environmental hazards even though we produce and use more oil products. This process improves ideality – that is inventive.



[a]Adapted from "Introduction to TRIZ (Ideality, Resources, and Enabling Technologies)." https://www.youtube.com/watch?v=WzfhH4Lm2AM, accessed July 23, 2020.

Table 3.1: TRIZ Contradiction Matrix (Engineering Characteristics).

Improving Feature ↓	Worsening Feature →	Weight of moving object 1	Weight of stationary object 2	Length of moving object 3	Length of stationary object 4	Area of moving object 5	Area of stationary object 6	Volume of moving object 7	Volume of stationary object 8	Speed 9	Force 10	Tension or Pressure 11	Shape 12	Stability of object 13
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 28, 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	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	Tension 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		35,40 24,31
13	Stability of object	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	40,31 2,1	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 moving object	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 stationary object		6,27 19,16		1,40 35				35,34 38					39,3 35,23
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	Brightness	19,1 32	2,35 32	19,32 16		19,32 26		2,13 10		10,13 19	26,19 6		32,30	32,3 27
19	Energy spent by moving object	12,18 28,31		12,28		15,19 25		35,13 18		8,15 35	16,26 21,2	23,14 25	12,2 29	19,13 17,24
20	Energy spent by stationary object		19,9 6,27								36,37			27,4 29,18

The following sources are used to create Tables 3.1 through 3.6.
Creating Minds, http://creatingminds.org/tools/triz/triz_contradiction_1.htm;
TRIZ 40, Solid Creativity http://www.triz40.com/aff_Matrix_TRIZ.php;
Darrell Mann and Simon Dewulf, Updating the Contradiction Matrix, https://www.researchgate.net/publication/237303841_Updating_the_Contradiction_Matrix

Table 3.2: TRIZ Contradiction Matrix (Engineering Characteristics).

Improving Feature ↓ / Worsening Feature →		Strength	Duration of moving objectt	Duration of non-moving object	Temperature	Brightness	Energy spent by moving object	Energy spent by stationary object	Power	loss of energy	loss of substance	loss of information	loss of time	Amount of substance
		14	15	16	17	18	19	20	21	22	23	24	25	26
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 18,22	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	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	Tension or Pressure	9,18 3,40	19,3 27		35,39 19,2		14,24 10,37		10,35 14	2,36 25	10,36 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 object	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 moving object	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 a 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	Brightness	35,19	2,19 6		32,35 19		32,1 19	32,35 1,15	32	19,16 1,6	13,1	1,6	19,1 26,17	1,19
19	Energy spent 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	Energy spent by stationary object	35				19,2 35,32					28,27 18,31			3,35 31

Table 3.3: TRIZ Contradiction Matrix (Engineering Characteristics).

Improving Feature ↓ / Worsening Feature →		27 Reliability	28 Accuracy of measurement	29 Accuracy of manufacturing	30 Harmful factor acting on object	31 Harmful side-effects	32 Manufacturibility	33 Convenience of use	34 Repairability	35 Adaptability	36 Complexity of device	37 Complexity of control	38 Level of automation	39 Productivity
1	Weight of moving object	3,11 1,27	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	25,26 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	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	Tension 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	1,32 17,28	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 object		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 28,25	27,3 15,40	15	29,35 10.14
15	Duration of moving object	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 stationary object	34,27 6,40	10,26 24		17,1 40,33	22	35,10	1	1	2		25,34 6,35	1	10,20 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	Brightness		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	Energy spent 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	Energy spent by stationary object	10,36 23			10,2 22,37	19,22 18	1,4					19,35 16,25		1,6

Table 3.4: TRIZ Contradiction Matrix (Engineering Characteristics).

Improving Feature ↓ / Worsening 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	11 Tension or Pressure	12 Shape	13 Stability of the object
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	Waste 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	Waste 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	Waste 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 34,7	35,3 22,5
26	Amount of substance	35,6 18,31	27,26 18,35	29,14 35,18		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	15,29 28,11	15,9 14,4	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	Accuracy of measurement	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	Accuracy of manufacturing	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	Harmful factors acting on object	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	Harmful side-effects	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	Manufacturability	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	11,13 1
33	Convenience of use	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	Repairability	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	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	Complexity of a device	26,30 34,36	2,36 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	Complexity of a control	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	Level 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

***Table 3.5**:* TRIZ Contradiction Matrix (Engineering Characteristics).

Improving Feature ↓	Worsening Feature →	Strength 14	Duration of moving object 15	Duration of stationary object 16	Temperature 17	Brightness 18	Energy spent by moving object 19	Energy spent by stationary object 20	Power 21	Waste of energy 22	Waste of substance 23	loss of information 24	loss of time 25	Amount of substance 26
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	Waste 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	Waste 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	Waste 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	Amount 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	Accuracy of measurement	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	Accuracy of manufacturing	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	Harmful factor acting on object	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	Harmful side-effects	15,35 22,2	15,22 33,31	21,39 16,22	22,35 2,24	19,24 39,32	2,35 6	19,22 18	2,35 18	21,35 2,22	10,1 34	10,21 29	1,22	3,24 39,1
32	Manufacturability	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	Convenience of use	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	Repairability	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	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	Complexity of a device	2,13 26	10,4 28,15		2,17 13	24,17 13	27,2 29,28		20,19 30,34	10,35 13,2	35,10 28,29		6,29	13,3 27,10
37	Complexity of a control	27,3 15,28	19,29 39,25	25,24 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	Level of automation	25,13	6,9		26,2 19	8,32 18	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	10,20 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

Table 3.6: TRIZ Contradiction Matrix (Engineering Characteristics).

Improving Feature ↓ / Worsening Feature →		Reliability	Accuracy of measurement	Accuracy of manufacturing	Harmful factor acting on object	Harmful side-effects	Manufacturibility	Convenience of use	Repairability	Adaptability	Complexity of device	Complexity of control	Level of automation	Productivity
		27	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
21	Power	19,24 26,31	32,15 2	32,2	19,22 31,2	2,35 18	26,10 34	26,35 18	35,2 10,34	19,17 34	20,19 30,34	19,35 16	28,2 17	28,35 34
22	Waste 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	Waste 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	Waste 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	32,1 10	35,28	6,29	18,28 32,10	24,28 35,30	
26	Amount 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	13,25 8,24	13,35 1	27,40 28	11,13 27	1,35 29,38
28	Accuracy of measurement	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	Accuracy of manufacturing	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	Harmful factors acting on object	27,24 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	Harmful side-effects	24,2 40,39	3,33 26	4,17 34,26							19,1 31	2,21 27,1	2	22,35 18,39
32	Manufacturability		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	35,1 10,28
33	Convenience of use	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	Repairability	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	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	Complexity of device	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	Complexity of control	27,40 28,8	26,24 32,38		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	Level 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 27,2	

***Table 3.7*:** TRIZ Contradictions Matrix explanations.

No.	Parameters	Description
1	Weight of moving object	The mass of the moving object which gravitational force acts on it (weight). The force that the moving body exerts on its support or suspension.
2	Weight of stationary object	The mass of the stationary object in a gravitational force acts on it (weight). The force that the stationary body exerts on its support or suspension, or on the surface on which it rests.
3	Length (or angle) of moving object	Any linear or angular dimension, involving a moving object with respect to its surroundings. It can be any distance: linear or rotational, small or large distance (tolerance, depth, height, etc.).
4	Length (or angle)of stationary object	Any linear or angular dimension, involving a stationary object with respect to its surroundings.
5	Area of moving object	Any geometrical dimension involving surface or surface area occupied by the moving object, either internal or external, of a moving object.
6	Area of stationary object	Any geometrical dimension involving surface or surface area occupied by the stationary object, either internal or external, of a stationary object.
7	Volume of moving object	Any cubic measure of geometrical dimension occupied by the moving object with respect to its surroundings.
8	Volume of stationary object	Any cubic measure of geometrical dimension occupied by the stationary object with respect to its surroundings.
9	Speed	Rate of position change of an object in time or rate of any kind of process or action. Speed can be relative or absolute, linear or angular.
10	Force	Force measures the interaction between systems. In Newtonian physics, force = mass x acceleration. In TRIZ, force is any interaction that is intended to change an object's condition (its magnitude and directions).
11	Stress or pressure	Stress is the amount of force applied per unit area, experienced by an object (it can be tensile, compressive, bending, torsional, static or dynamic). Pressure is the amount of force that is applied per unit area.

Table 3.7: TRIZ Contradictions Matrix explanations (continued).

No.	Parameters	Description
12	Shape	The external contour or appearance characteristic of an object or a system.
13	Stability of the object's composition	The wholeness or integrity of the system; the relationship of the system's constituent elements. Wear, chemical decomposition and disassembly are all decreases the stability of an object. Increasing entropy is decreasing stability.
14	Strength	The extent to which the object is able to resist changing in response to force. Resistance to breaking/ failure. The capacity of an object to withstand a critical force or pressure before it fails.
15	Duration of action by a moving object	The time that a moving object or system takes to perform an action without fails. Service life, mean time between failures is a measure of the duration of an action.
16	Duration of action by a stationary object	The time that a stationary object or system takes to perform an action without fails. Service life, mean time between failures is a measure of the duration of an action.
17	Temperature	The thermal condition of the object or system. Temperature is a measurement of the average kinetic energy of the molecules in an object or a system. Includes other thermal parameters, such as heat capacity, that affect the rate of change of temperature.
18	Illumination intensity	Light flux per unit area, also any other illumination characteristics of the system such as brightness, light quality etc.
19	Use of energy by moving object	The measure of a moving object's capacity or ability for doing work. In classical mechanics, energy is the product of force x distance. This includes the use of energy provided by the super-system (such as electrical energy or heat). Energy required doing a particular job.
20	Use of energy by stationary object	The measure of a stationary object's capacity or ability for doing work. In classical mechanics, energy is the product of force x distance. This includes the use of energy provided by the super-system (such as electrical energy or heat.) Energy required doing a particular job.
21	Power	The time rate at which work is performed. The rate of use of energy.

***Table 3.7*:** TRIZ Contradictions Matrix explanations (continued).

No.	Parameters	Description
22	Loss of energy	A part of energy that does not contribute to the job being done. See 19. Reducing the loss of energy sometimes requires different techniques from improving the use of energy, which is why this is a separate category.
23	Loss of substance	Loss of substance may be partial or complete, permanent or temporary: loss of some of a system's materials, substances, parts or subsystems.
24	Loss of information	Loss of information may be partial or complete, permanent or temporary: loss of data or access to data in or by a system. Frequently includes sensory data such as aroma, texture, sound.
25	Loss of time	Time represents the duration of an activity. Improving the loss of time means reducing the time taken for the activity. â€˜Cycle time reductionâ€™ is a common requirement.
26	Quantity of substance/the matter	The number or amount of a system's materials, substances, parts or subsystems which might be changed fully or partially, permanently or temporarily.
27	Reliability	A system's ability to perform its intended functions in predictable ways and the same repeated result under the same conditions.
28	Measurement accuracy	The closeness of the measurements to a specific value of a property of a system. Reducing the error in a measurement increases the accuracy of the measurement.
29	Manufacturing precision	The extent to which the actual characteristics of a system or an object match the specified or required characteristics.
30	External harm affects the object	Susceptibility of a system to externally generated (harmful) effects.
31	Object-generated harmful factors	A harmful effect is one that reduces the efficiency or quality of the functioning of an object or a system. These harmful effects are generated by an object or a system, as part of its operation.
32	Ease of manufacture	The degree of facility, comfort or effortlessness in manufacturing or fabricating an object or a system.
33	Ease of operation	Operation can be done easily, without difficulty or effort. Simplicity: A process is not easy if it requires a large number of people, large number of steps in the operation, needs special tools and so on. & quote; Hardâ€™ processes have low yield and â€˜easyâ€™ processes have high yield; they are easy to do right.

Table 3.7: TRIZ Contradictions Matrix explanations (continued).

No.	Parameters	Description
34	Ease of repair	Quality characteristics such as convenience, comfort, simplicity and time to repair faults, failures or defects in a system.
35	Adaptability or versatility	The extent to which a system/object positively responds to external changes. Also, a system that can be used in multiple ways in a variety of circumstances.
36	Device complexity	The number, interaction, and diversity of elements and element interrelationships within a system. The user may be an element of the system that increases the complexity. The difficulty of mastering the system is a measure of its complexity.
37	Difficulty of detecting and measuring	Measuring or monitoring systems that are complex, costly, require much time and labor to set up and use, or that have complex relationships between components or components that interfere with each other all demonstrate â€˜difficulty of detecting and measuringâ€™. Increasing cost of measuring to a satisfactory error is also a sign of increased difficulty of measuring.
38	Extent of automation	The extent to which a system or object performs its functions without human interface. The lowest level of automation is the use of a manually operated tool. For intermediate levels, humans program the tool, observe its operation, and interrupt or reprogram as needed. For the highest level, the machine senses the operation needed, programs itself, and monitors its own operations.
39	Productivity	The number of functions or operations performed by a system per unit time. The time for a unit operation. The output per unit time, or the cost per unit output.
	Explanation of Moving objects	Objects which can easily change position in space, either on their own, or as a result of external forces. Vehicles and objects designed to be portable are the basic members of this class.
	Explanation of Stationary objects	Objects which do not change position in space, either on their own, or as a result of external forces. Consider the conditions under which the object is being used.

Information in Table 3.7 is adapted from “Domb, E., 1998. The 39 features of Altshuller’s contradiction matrix. TRIZ J.” Also see: https://www.sciencedirect.com/topics/engineering/altshuller

Table 3.8: Altshuller's TRIZ – 40 Principles.

Principles	**Principles**
1. Segmentation	21. Rushing through
2. Extraction (taking out)	22. Convert harm into benefit
3. Local Quality	23. Feedback
4. Asymmetry	24. Mediator (intermediary)
5. Combination (merging)	25. Self-service
6. Universality	26. Copying
7. Nesting	27. Inexpensive short life
8. Counterweight (anti-weight)	28. Replacement of a mechanical system
9. Prior Counteraction	29. Use pneumatic or hydraulic systems
10. Prior Action	30. Flexible film or thin membranes
11. Cushion in Advance	31. Use of porous materials
12. Equipotentiality	32. Changing the colour
13. Inversion (the other way round)	33. Homogeneity
14. Spheroidality- Curvature	34. Rejecting and regenerating parts
15. Dynamicity	35. Parameter Change
16. Partial, overdone or excessive action	36. Phase transition
17. Moving to a new dimension	37. Thermal expansion
18. Mechanical vibration	38. Use strong oxidisers
19. Periodic action	39. Inert environment
20. Continuity of useful action	40. Composite materials

Source of Table 3.8: Altshuller G. 40 Principles: TRIZ Keys to Technical Innovation. Technical Innovation Center; 2001.