5 Basic TRIZ

In 1946, a Russian naval patent officer, Genrich Altshuller, noticed similarities in invented solutions from different fields. He had the temerity to suggest to Stalin that he could improve inventing and was sent to a Siberian Gulag for thinking too much. Fortunately for him, the labour camp was also home to many other thinkers, including physicists, chemists, engineers and mathematicians, who helped him continue the development of his theories. After Stalin's death and his subsequent release, he continued his research via an 'underground university' of like-minded scientists. Anyone could join, provided they analysed a few thousand patents!

After some 1,500 person-years of research, including analysis of over 200,000 patents, Altshuller developed and refined the Theory of Inventive Problem Solving (or 'Teoriya Resheniya Izobretatelskikh Zadatch' in Russian, which gives the acronym TRIZ, pronounced 'trees'). What Altshuller discovered is that most patented ideas use a relatively small number of objective principles and are based on a finite number of physical, chemical and geometric effects. TRIZ is the condensation of this knowledge. He also found that 90% of problems had already been solved, often in another scientific field, but the inventor lacked knowledge of these existing solutions. Another finding was that only 1% of the real inventions came from real scientific discovery (32% of inventions are from personal knowledge of the inventor, 77% are from within the company and 95% are from within the industry).

At a recent TRIZ conference it was stated that it might take five to seven years for someone to get to be an expert in TRIZ. We are not going to try to make you an expert here, but by the end of the chapter you will understand some of the key principles and will be able to use the basic TRIZ tables and lists.

TRIZ principles

In its simplest form TRIZ may be seen to represent some easy questions. These are represented in this book in various ways.

As TRIZ contains generalisations of many principles, the first step is to create a standardised abstract model of your problem that fits into one of the TRIZ models. This can then be used to find a generalised solution which you can interpret to discover an answer that may solve your particular problem (Figure 5.1).



Fig. 5.1 Getting over the invention wall

This is not too unusual as it is similar to how people normally approach many situations. First they work to understand the problem in terms of their own personal interpretation of the situation. Given this understanding they then consider various approaches with which they are familiar, select one and try it out in practice.

Function

All parts of a device perform functions. Whenever something happens, a function has been performed. There are *primary functions*, which perform the main desired effects, and *secondary functions*, which support the primary functions (note the similarity with primary and secondary functions of Value analysis in Chapter 1).

To find out what is happening, you can use chunking (as in Chapter 1) to zoom either in to the detail (even to the molecular level) or out far enough to see the big picture.

To identify functions, look at what is being done and the results of those actions. Results of an action produce change of some sort, which hopefully is what is required. To assess the change, it should be measurable, which means it will have a value and units, such as of heat, shape, motion, energy, etc.

Harm

In TRIZ, functions are either useful and hence desirable, or they are *harmful*. This is a slightly different use of the word 'harm' to normal English usage as it does not imply that anyone is hurt, simply that net value is adversely affected and that the harm should be eliminated as far as is possible. All financial costs are considered as harmful, as are things which cost in different ways, such as taking up time or causing people anxiety of any form.

Just as there are primary useful functions, there are also primary harmful functions, which are the main undesirable factors and hence become the first targets for removal.

Harmful functions are often unintentionally caused as a side effect of useful functions, and may be identified by looking at causal relationships, as described in Chapter 1.

The ideal solution

TRIZ asks you to think about what an ideal solution would be like. For example, if you have a hall where you want people at the back to hear you clearly, then an ideal solution might be where the hall itself becomes the amplifier, eliminating the need for a microphone. Although this may be considered silly, such consideration of *ideality* leads to useful attention to how the shape and surfaces of the room affect the transmission of sound.

A critical effect of considering an ideal is that it focuses thinking on functions, both useful and harmful, and how these might be enhanced or eliminated.

The ideal solution does zero harm and provides maximum desirable functionality.

Trimming

TRIZ invites you to trim away unnecessary devices by thinking about how some parts of the system may deliver the functions that currently other parts deliver. We tend to add a device every time we need another function. Many systems can be trimmed if we think carefully about how to deliver the functions we want.

A trimmed system not only costs less, it also has less scope for harmful functions to appear, and is thus doubly desirable.

A simple example would be an assembly where instead of screwing one part to another the shape of the parts allows them to be clipped together. Screw, glue or other fasteners have been trimmed away by changing the shape of the parts.

Substances and fields

In all devices there are two basic elements: parts of the system, or *substances*, and the medium through which they interact, or *fields*. The substances can include parts of the system, such as wheels and cutting edges, and also external elements such as the atmosphere and a rock that is being drilled. The field may be mechanical connection, electromagnetic, hydraulic, chemical, acoustic, etc.

Problems often occur because either the parts interact inefficiently or they interact when they should not. By identifying these 'substances' that interact and the field through which they interact, you can discover where improvements are required and hence a focus for invention.

Evolution

TRIZ asks you to think about how devices and systems evolve. There are predictable patterns of evolution that can be used as a focus for attention, including:

- *Increasing ideality*. The ideality of a system is defined as the sum of its useful effects divided by the sum of its harmful effects. The system can thus be evolved through increasing its benefits or by decreasing factors that either cause problems or add no significant value.
- *Improving interfaces*. Parts of the system work together better through improvements in the substance-field relationships.
- *Harmonisation*. Where the system involves multiple vibrations or oscillations of any kind, unless they are harmonised, they will interfere with one another. This can include the likes of drills that vibrate at the harmonic frequencies of the target materials.
- *Completing the system*. All systems have a source of energy, parts that use the energy to deliver the function of the system, a way of channelling the energy to the delivery function and a control system. A weakness in any of these may limit the whole system. The energy delivery system in particular can be problematic and is the subject of many patents.
- *Increasing dynamism*. Things that were fixed tend to become movable, to eliminate problems resulting from them being fixed or to increase flexibility. For example, in aircraft, undercarriage became retractable and wings movable.
- *Inward focus*. As the larger systems problems are resolved, remaining problems tend to be at increasingly levels of detail. With physical problems, you thus tend to end up at the atomic level (which you can, of course, go directly to with the simple science of Chapter 2).
- *Extending the system*. When a system has reached its ideality limit, further improvement can be achieved by combining it with other systems or adding new parts.

Contradictions

The heart of inventing with TRIZ is the identification and resolution of contradictions. Indeed, Altshuller said that all inventive problems contain at least one contradiction. This changes inventing from 'dreaming up ideas' to 'finding and resolving contradictions', which is a far more structured approach.

There are two types of contradiction: technical and physical. Figure 5.2 shows the structure of a technical contradiction. A desirable function A uses a second function B which has undesirable effects, either causing a third function C which is harmful or harming an existing function D. For example, you could evenly spread light over a large car park by having a tall lamp post, although this would require a high-strength post to hold the large light far above the ground. Thus A (distant light source) needs B (tall strong post) which leads to C (high cost) and D (difficult maintenance).



Fig. 5.2 Technical contradiction

Physical contradictions occur where the two opposing physical states are required, for example a blacksmith wants the horseshoe to be hot enough so the metal is workable, but he would also like it to be cool enough to hold. The 'harmful' solution is to use tongs, which are not as easy to use as using his fingers. To address a contradiction, we can change the functions that cause harm or we can add functions that prevent or reduce the harm. Questions to resolve contradictions take the form of 'How else can I ...?' or 'How can I reduce or eliminate ...?'

So with the lamp post I can solve my problem of a heavy light source high above ground by placing a light mirror at the top of the post and beaming light from a source on the ground which is then reflected all over the car park! This solution also enables light bulbs to be changed more easily.

For physical contradictions in particular, separation in time, space or scale often works. The blacksmith's tongs use separation in space, which could be reduced with protective gloves. You could also change the 'scale' of the working hands by using a large machine which can form the horseshoe quickly and easily.

When we do change the solution, it is a good idea to check that we have not created more harmful contractions (for example by asking, 'How is the desirable function of 'being able to withstand rough treatment' affected?').

Using contradictions and principles

Appendices A, B and C detail Altshuller's key discoveries about inventions and can be used as a set of tools for scientific inventing. The approach to use is as follows.

1. Critical parameters

Use the table of 39 Parameters (in Appendix A) to identify critical parameters of your problem.

For example, my lamp post problem had weight of nonmoving object (parameter number 2) and length (parameter number 4) as critical parameters. I might also think about number 34, repairability (maintenance).

2. Contradictions

Identify contradictions between these parameters, where one parameter causes problems with another problem. In our

example, contradictions include (a) that the weight of the light source combined with the distance from the ground causes undesirable force on the post, and (b) the distance from the ground makes it difficult to repair.

3. Find numbers of resolution principles

Use the Contradictions Matrix (in Appendix B) to find the numbers for the Principles that can be used to resolve the contradictions. For contradiction (a) in step 2, the feature to change is 'weight of stationary object' and undesirable result is 'force'. Looking this up in the matrix gives Principles 8, 10, 19 and 35.

For contradiction (b), weight against repairability, this gives Principles Nos. 2, 27, 28 and 11.

4. Investigate the resolution principles

Use the numbers from the Contradiction Matrix to look up resolution in the list of 40 Principles (in Appendix C).

In contradiction (a), Principle 8 is 'counterweight', which might be achieved with tension wires on the sides of the post. Principle 10 is 'prior action' – maybe we could shield the lamp from the wind so it is less likely to be bent at an angle where its weight it too great a force on the post.

For (b) we have Principle 2, 'extraction'. Extract the disturbing part of the system and place it elsewhere, so we have solved the problem by placing the light source on the ground. See if you can get other ideas from the Principles.

Simplifying the principles

We can reconstruct the 40 Principles of TRIZ to fit into a small number of groups and in doing so help you think about how they work. However, be aware that any grouping of this kind potentially simplifies to the point where something may be missing. If our grouping does not work well on a problem then go back to the original list. Some principles look like they may fall into two groups. Where this is true we have chosen what we found to be the most obvious group. For example, one might argue that use of composite material is about changing the physical structure rather than the chemical structure.

Try to see how these principles work together to solve problems. What you are doing is solving the problem by managing the action as it occurs, managing the time that things occur, designing how parts work together (as place or shape or structure) and how much action you get for your money (chemical action). If you can see these generalities then you can put them together in combinations which should lead to novel solutions.

Any of the groups may yield a solution to a problem as there are many ways to crack an egg. To crack an egg you can use Time (quickly), Shape (thin blade), Chemical action (phase transition with lasers), Place (slice off the top) and Physical structure (Porosity/Local Quality: suck the egg out).

Generic principles

Let us start with the group of principles which are so generic that they may be applied to any situation, not just the 'normal' invention domain of technology.

The Generic Principles are: Combination, Universality, Counterweight, Prior counteraction, Inversion, Partial, overdone or excessive action, Convert harm to benefit, Feedback, Selfservice, Copying, Inexpensive short life, Inert environment (5, 6, 8, 9, 13, 16, 22, 23, 25, 26, 27, 39).

These portray how we manage the action we have. If we wanted to manage the work of a football team all these could come into play. They suggest we consider ways of managing the interaction of the parts and the whole. They therefore can be used for any problem you want to solve. They are commonly utilised in protecting controlling, and managing the overall environment.

Time principles

The principles for time are: Extraction, Prior action, Cushion in advance, Dynamicity, Mechanical vibration, Periodic action, Continuity of useful action, Rushing through, Rejecting and regenerating parts (2, 10, 11, 15, 18, 19, 20, 21, 34). These all suggest you consider when something is going to happen and how fast.

They are also fairly generic in that they can be applied to business or even planning a holiday. But they are placed in this group to help you think through all your time options.

Shape principles

There are three shape principles: Asymmetry, Spheroidality and Thermal expansion (4, 14, 37).

Take any parameter or feature of your device and think about how you can change its shape to a more complex shape along one, two or three dimensions, and you can do this as it operates by thermal expansion.

These are more technological in nature but there are also parallels with more general problems. For example, what would an asymmetric policy for answering customer calls be?

Place principles

The two place principles are: Equipotentiality and Move to a new dimension (12 and 17). These suggest doing something where it is already or doing it in a different direction.

Physical structure principles

The physical structure principles are: Segmentation, Local quality, Nesting, Mediator, Replacement of a mechanical system, Use pneumatic or hydraulic systems, Flexible film or thin membranes, Use of porous materials, Changing the colour, Homogeneity (1, 3, 7, 24, 28, 29, 30, 31, 32, 33).

These are all about how the various parts interact themselves (as opposed to how we manage their interaction in the Generic group). They interact according to their properties (including colour) and the way they are connected.

Chemical structure principles

The chemical structure principles are: Transforming physical or chemical states, Phase transition, Use strong oxidisers, Composite materials (35, 36, 38, 40).

They suggest changing how something is working by changing the chemical activity (what is happening via the bonds they form).

TRIZ thinking

After working with TRIZ for a while, you will find its principles invading your approaches to solving problems. Here are a few examples of how TRIZ thinking can be used, starting with some problems from around the house.

The blocked sink

Recently, Graham's kitchen sink was blocked, so he went for the standard solution, a sink plunger, but it did not work. Solution number two was to use chemicals and hot water. After a long time spent emptying the sink, pouring hot water and dissolving stuff down the plug hole, the sink was still blocked.

So now Graham started using TRIZ thinking. He defined the problem as 'how to move solid substance in a tube'. The constraint was that he could access the substance only from the sink end or the outside pipe.

What was needed was to create a pressure wave in the fluid sitting over the blockage. The plunger did not create a good pressure wave precisely because it was flexible. Why is it flexible? To create a good seal at the sink. So here is our contradiction. The plunger must be flexible to create the seal which is needed to create the pressure but it also must be solid so it transmits a high-impact pressure wave.

The next question was how to get a good seal without flexibility. This could be achieved with something which fitted

the plughole perfectly. Looking around, a coffee mug was found (it had been there all along). It fitted beautifully and with a single sharp pull, the blockage was removed.

Mowing the grass

I have a bit of a problem mowing my grass, not so much the cutting bit but the tidying up and putting things away bit. To run the electric mower I need power. I run the extension lead from inside the house to the outside. Fine. I cut the front lawn and need to move the mower round the back.

The problem now is that I have grass on my trousers and shoes and I need to take out the extension lead and move it to the back. So I brush down my trousers, take off my shoes, go into the house and remove the lead only to have to put my shoes on again and walk round the back with the mower. It takes such a lot of time and I never manage to get all the grass off me!

What does TRIZ suggest? My contradiction could be stated as Speed against harmful factors acting on an object outside (9 goes up and 30 goes up too). As my speed goes up more grass gets inside the house, which is outside the garden (you have to think laterally sometimes!)

One Principle suggested from the table is number 1, Segmentation – or divide an object into independent parts, which could lead to my extension cable being divided into two parts. One runs from the house to the window and the second from that point up to my mower. Now I can disconnect the mower while out in the garden. And I have a second extension cable already set up for the back of the house (Principles number 10, Prior action and 26, Copying – cheap of course!)

So I can pack all away just once and take a bit more time getting rid of the grass before coming back inside.

An engine hatch

Here is an example of a problem we solved using TRIZ when building a large (six-foot wingspan) radio controlled model plane. We had a fuel tank which had to sit at the front of the plane. It had three pipes to be connected to it. We could only place the pipes onto the fuel tank if they were long enough to extend into the middle of the plane where we had access from the top. But if they were this long we knew that they would risk being crushed as we pushed the fuel tank into the front of the plane.

This is a contradiction between the parameters of Length of moving object and Reliability. According to the Contradiction Matrix it can be solved by Principles 10, 14, 29 or 40, that is: Prior action, Spheroidality, Use pneumatic or hydraulic systems or Composite materials.

The last two give us ideas but involve changing the pipe more than we want to. Spheroidality is interesting in that we could think or how we might get the pipes to be rolled into a ball as they are placed inside the front of the plane.

We chose Prior action: we would build a hatch which means we can get to where we want to fit the pipes. But we then had a problem of how to secure the hatch without ugly and complex devices. We saw this as a Reliability vs. Waste of time contradiction. TRIZ suggests Principles 10, 30 and 4 (Prior action, Flexibility and Asymmetry).

We had thought of a hatch with simple straight sides across the nose of the plane. Asymmetry made us think of cuts at an angle in the thick balsa wood. This also fitted with the Principle of Self-service, how to get the plane to hold the hatch down. The hatch would now only slide across and could not pull out vertically.

But we had another contradiction. If we made the hatch so well that there was not an ugly gap it might bind to the plane through too much friction (Accuracy of manufacturing vs. Harmful side effects). Again TRIZ suggests Asymmetry and New dimension. So we extended our asymmetry so that the cuts across the balsa were such that we had a wedge-shaped hatch, as in Figure 5.3. Now the hatch binds only when it buts up against the body. We had one final problem to solve. How to stop the hatch sliding out? (as it is wedge shaped it has no friction once slightly away from the body). We felt we needed a

Mediator, something between the body and the hatch. We did not want it on the outside so we chose New Dimension (on the inside of the plane body).



Fig. 5.3 Plane hatch example

How were we to fit a rod through the body into the hatch so the body and the hatch would be held together? We did not have a drill long enough for such a small hole, however. So we chose another TRIZ Principle: Self-service.

We made the end of our rod slightly flat and put it into the drill and used the rod to drill its own and perfect hole!

Printing

Our printer would not print properly as the pages were not pulling through. On looking at the situation, it was clear that the problem was the paper. It was a set of sheets of labels and the sheets were binding to each other.

Putting a single sheet in the tray did not work either, as the printer wheel could not grip the paper. So we needed several sheets, but the friction was too great when we had sheets next to each other. The question was how to solve the friction problem.

One TRIZ Principle is to insert an intermediary object. Perhaps if we inserted low friction sheets between the label sheets it would feed through a problem. But then it would print on sheets we did not want to print on.

So we add a page of printing nothing to every other sheet. It works perfectly!

Cleaning with TRIZ

For most people the task of washing dishes, if not done by machine, is a chore and one which you either resign yourself to or argue about who is going to do it.

We can improve the situation if we look in detail at the task, just as if we were thinking it through as a manufacturing process. We have to look for ways to change the unpleasant portions of the task, so that the 'operator' is happy to execute the entire process.

The first step is to break the task down into stages as follows:

- Remove the leftover food from the plates (not pleasant).
- Stack dishes and fill a bowl with water and washing-up liquid.
- Begin dipping and wiping, maybe with gloves on and maybe not, depending on operator preference.
- Rinse.
- Drain and leave to dry, or wipe and dry, depending on operator preference and available space.

If we look at the whole operation, we can see that how it begins is nicer than how it finishes, except for the scraping of food off plates. The first plates are dipped in nice, warm, soapy water, which we can enjoy. Towards the end, the water gets pretty mucky and not so nice to use.

To overcome these 'harmful' effects, we can use the principles of Preliminary action and Segmentation. Can we change something that will allow us to end up with almost clean water so the task is still pleasant? Can we break down this part of the task so that we complete the stages in a different way? Our current process takes a plate and has a cleaning operation applied to it thoroughly to remove all the dirty substances. For each plate this takes a given amount of time. Typically most of the substance is removed early on and the remaining time is spent ensuring that the entire plate is clean.

When we break this process down into two stages, we can see alternatives. Instead of thoroughly cleaning each plate, what if we partially clean the plate (one second at most) and dip a second plate into the clean water to soak? This option quickly and 'mostly' cleans all of the dishes, and leaves us with a set of plates that we can now enjoy fully cleaning.

An analogous situation is cleaning the car. The unpleasant job is getting rid of all that stuck on dirt. The nice part is taking time to carefully restore the pristine finish and to play with clean water while doing so.

Now we can see that there is an opportunity to enjoy washing dishes or the car by making the time spent mostly playing with the water and only partially doing the less enjoyable parts.

The dishwashing process can be further improved, by introducing a new stage. If we place a large paper bag in the sink and have a tap slowly running water into the bag, we can quickly remove most of the food from the plate with a quick wipe under the tap. The food is being stored in the bag and when all plates have been quick wiped under the tap, simply squash the bag down hard to remove excess water and place in a plastic bin for emptying out in the compost pile.

This combines the TRIZ principles of Preliminary action again and Substitution (placing a bag in the sink so that the material can be removed easily). You may need to experiment a bit with the type of paper bag.

It may seem silly changing how we do the dishes, but surely it is even more so to continue doing something in a way that you do not enjoy, when you can inventively do it in a way that you can enjoy. This process really does work for most people who have tried it. And, when you have proven that the process of washing dishes can be improved, you can tackle other tasks like cutting the grass, hedges, weeding, etc.

The point is that TRIZ can have an impact on everyday life. Mundane and difficult tasks can be improved if we can convince individuals to get out of the habit of doing things the way they've always done them, and look for ways to do them differently. Nearly every job can be improved and made more enjoyable if it's approached the right way, even something as simple as washing the dinner dishes.

The 'no board' whiteboard

Graham helped a company called Intralon that makes whiteboards to design and develop a future generation product using our inventive processes, including TRIZ. The whole process was completed in less than eight months, from idea to manufactured product.

What do we have now?

Whiteboards are a very common device in businesses for writing and sharing ideas. A problem with this is that you cannot take what you write with you. A fairly common solution to this is the electronic whiteboard, which will record and print off what you write on it. The downside of this innovation is that the board is fairly heavy and big to carry around and costs a lot to produce and buy, which means it is limited to professional markets where the cost can be justified by time savings from the board's use. The results also need to be photocopied if others are to receive copies.

What do we want?

The first thing for us to consider is *ideality*. The question to ask is what we *really* want from such as device, keeping *only* what gives us a benefit. The answer is that we want to see where the pen has been, as soon as it has been there, and to be able to capture and share the resulting lines.

So we need a pen, a display device and a recording device. The goal is to get the pen to tell the recording device directly where the pen is. We can say that the pen 'knows' where it is (this may need some thinking about but is essentially true). An ideal solution is to get the thing that knows things to do the work, not some other device.

Solutions and contradictions

When we considered this, we saw that the pen is always visible although our brains are not good enough to track its movements to see what has been written over any period of time. So we asked, 'Why don't we just watch the pen and record where it goes?' We could thus watch the move pen with a camera of some sort.

A Contradiction here is the person with the pen may get in the way of any device watching the pen. A TRIZ principle to resolve this might be use of Another dimension. So we could watch the pen from one side or up high, where the writer does not block the field of view of the watching device.

Another Contradiction is visibility of the pen to the tracking device. How well does the pen stand out in any environment? We could ask people to write in the dark and use a luminescent pen but the customers may not like this. The simple TRIZ Principle of Changing the colour works here, although by 'Colour' we mean change to infra-red. So now we put a little infra-red transmitter in the pen so that is the only thing we watch and record!

The eventual solution, after a number of further sessions of identifying and resolving contradictions, is that Intralon have replaced a big heavy board with a simple inexpensive camera which detects only the infra-red signals from the pen and (with a smart bit of software) passes this to a computer which records where the pen is.

The computer can now print off everywhere the pen has been (so recording any writing) or, if used with a projector, can display in light what the person is writing. So now, any wall becomes a whiteboard of any size and you even can choose whatever colour you want with the same pen!

So we have reduced cost, reduced weight (to a small, very portable box), made a system which will work anywhere, with

almost any size of 'whiteboard', with electronic results that can immediately be e-mailed to anyone else. Not bad for just a few hours TRIZing!!