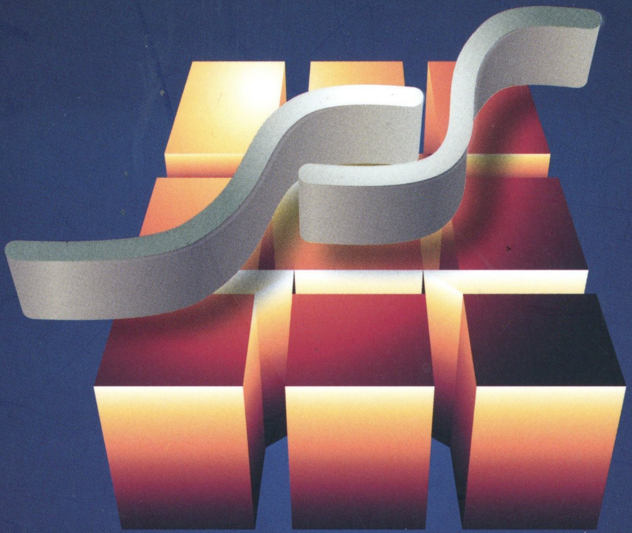
Theory of Inventive Problem Solving

TRIZ

Systematic Innovation in Manufacturing



Yeoh Teong San, Ph.D.
Yeoh Tay Jin
Song Chia Li

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Contents

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Yeoh Teong San was formerly working in Intel Corporation in Malaysia as a Principal Engineer for the past 25 years. He has a Ph.D. in Applied Physics. His current focus is on training, proliferation, and application of TRIZ into universities, colleges, schools, and industries. Both Yeoh Tay Jin and Song Chia Li are working in Intel Corporation in Malaysia. Yeoh Tay Jin has a B.Eng (Mechanical) and is a Staff Engineer, whereas Song Chia Li has a B.Eng in Manufacturing & Management and is an Engineer. All three are Level 3 certified by the International MATRIZ Association. This book is based on their collective experience in proliferation, adoption and application of TRIZ across various countries including China, Costa Rica, India, Malaysia, Philippines, United States, and Vietnam.

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Preface

The motivation for this book has primarily been driven by students' request for a book which they can reference to, especially in the application of the various TRIZ methodologies and tools in the manufacturing environment. For those who have understudied TRIZ, it has always been a challenge to understand the concepts, theories and how the methodologies and tools need to be applied effectively and in a correct manner. This book was written as an attempt to clarify them as extensively as possible.

TRIZ which is a systematic approach to inventions was originated by Genrich Altshuller in Russia during the 1940's. TRIZ is an evolving science of innovation and the body of TRIZ knowledge constantly grows with new tools and methods being added. The key methodologies and tools as presented in this book correspond mostly to Classical TRIZ (Litvin et al., 2008). This book is intended for TRIZ students, practitioners and newcomers to the field, along with engineers and technical folks who are interested in systematic innovation. Since the focus of the book is on semiconductor manufacturing projects which were worked on, folks from other industries may find this book to be of interest as similar concepts can be applied to their particular field. Note that someone somewhere has already solved the problem similar to yours!

This book is composed of *12 chapters.* The introduction of TRIZ is in *Chapter 1* and helps to illustrate the uniqueness of TRIZ. This is followed by *Chapter 2* in terms of how it is different from a normal problem solving process. *Chapter 3* shows how TRIZ complements and strengthens the problem solving process, especially in problem identification and solution generation. The subsequent chapters starting with *Chapter 4* starts to unveil the fundamental concepts of what TRIZ practitioners need to know. This is then further dealt with in *Chapter 5* on Product Analysis.

Chapter 6 provides a systematic way of determining root cause. *Chapter 7* on Trimming is included to provide breakthrough thinking in terms of whether we can generate a better system by removing components, rather than adding more components which complicates the final system. Innovative ideas and new systems can be developed through Trimming. *Chapter 8* is a very important chapter dealing with conflicts or rather contradictions. When faced with conflicts, we normally compromise and try to find the optimum solution. In TRIZ, compromise is not an option and the objective is to resolve the contradiction. This normally results in elegant solutions which are innovative, yet simple and low cost.

Chapter 9 showcases 3 case studies in the manufacturing environment which helps illustrate the previous chapters. *Chapter 10* deals with another method of solving via Substance-Field Model. *Chapter 11* is on ARIZ (Algorithm of Inventive Problem Solving) which is one of the most rigorous and most comprehensive algorithms to solve a complex problem while having a boundary condition of minimal changes to the system which is typical of a manufacturing environment. A manufacturing case study will be used to illustrate the different models and tools used including Substance-Field Model and ARIZ to solve the problem. Finally, *Chapter 12* briefly summarizes the entire book. We hope that readers would gain a better insight of TRIZ along with its multitude of methodologies and tools which can be applied based on the situation, similar to a toolbox with many tools to choose from.

CHAPTER 1

Introduction

TRIZ pronounced as "treez" is a Russian acronym for "Teoriya Resheniya Izobreatatelskikh Zadatch". In English, it stands for "Theory of Inventive Problem Solving".

Here's a brief historical background of how TRIZ was developed. In the 1940's, a Russian patent engineer named Genrich Altshuller, discovered that problems, solutions and patterns of technical evolution were repeated across industries and sciences. This was based on a study of approximately 200,000 patents which were narrowed down to 40,000 innovative patents. These innovations used scientific effects outside the field from where the original problem was found.

There were a number of interesting findings (Altshuller, 2002). It was found that Engineering Systems progress towards Ideality by overcoming internal contradictions. These Engineering System evolutions are driven by objective laws. There are patterns to help develop the Engineering Systems further through trends of evolution. Details of Engineering System, Ideality and Contradictions will be explained in subsequent chapters. In addition, problems repeat across industries & sciences and it was found that the solutions used to solve these problems repeated correspondingly. The essence of these solutions was consolidated into the 40 Inventive Principles. One other interesting finding was that inventiveness could be taught!

TRIZ is a philosophy, a process, and a series of tools based primarily on the concept of resolving contradictions. Engineering Contradictions are the crux of many issues seen to date where compromise or trade-off is needed to balance between an improving versus a worsening characteristic. This is what's happening in current manufacturing environments and we probably are able to live with it for now; but as technology advances and equipment are being pushed harder, the equipment will break or deteriorate further. The manufacturing environment encompasses any kind of industry which uses equipment or tools in their manufacturing process. The concept of contradictions and how we resolve these contradictions will be discussed in subsequent chapters.

Brainstorming and its limitations

As most of us are aware, the typical problem solving process used is brainstorming whereby a group of people will meet up and "brainstorm" solutions to a problem. The brainstorming method does have its limitations where the quality and effectiveness of the solutions generated are highly dependent on the people who are present during the brainstorming. Good solutions will be derived if there are experienced and knowledgeable people in the group. However, if they were not present, then the brainstormed solutions may neither be effective nor produce the results needed. Even though the brainstorming group may have experienced people, they may sometimes face the other limitation of brainstorming which is called Psychological Inertia.

Psychological inertia and its impact to innovative brainstorming

Psychological Inertia deals with the resistance to change due to human programming. It poses many barriers to innovative brainstorming during problem solving. This is attributed to what a person had learnt previously in the form of rules and regulations, "do's and dont's"; along with books, television and those whom the person interacts with, which starts to create boundaries and restrictions in the person's mind.

Our brain is hardwired to search for "Have we seen this before?". Let's take the example of Figure 1.1 which is commonly found in psychology books under the topic of perception. If you are asked to determine the number of pictures seen (Mann, 2002), the typical answer is two i.e. two people facing each other (focus on black color) and a candle stick holder (focus on white color).

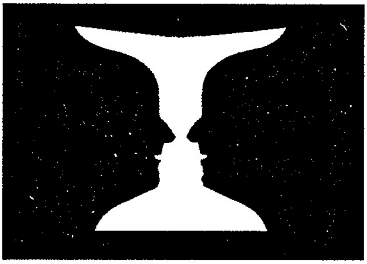


Figure 1.1 *Picture to illustrate brain hardwiring*

Since many of us may have seen this picture before, our brain will automatically do a search on "Have we seen this before?" and the answer of two pops up very quickly. However, on closer observation, there are more than two pictures. If you separate the picture into two halves, the bottom picture (white color) looks like a person with a hat and the top picture (white color) looks like an inverted clothes hanger. If you halve the bottom half of the picture, you'll see a person with a large tummy (focus on white color) facing to the left and another facing to the right. Notice that both persons are different i.e. the picture is not symmetrical (one of the 40 Inventive Principles i.e. Asymmetry which will be discussed later)!

If the picture is inverted (Figure 1.2), there seems to be two cars bumper to bumper (focus on black color). This is not exhaustive. As you study further, there are more pictures which may surface out. In the future, if you are shown this same picture, your response would be that you see more than two pictures!

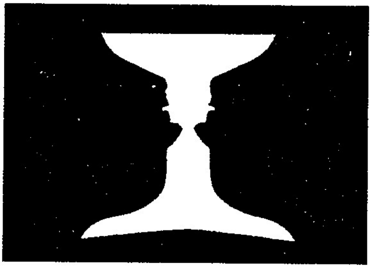


Figure 1.2 Picture to illustrate brain hardwiring - inverted

A number of studies have been conducted on the level of creativity over the age of individuals (Figure 1.3). It has been found that the peak of creativity ranges from ages 14 to the 30's. The level of creativity has been found to decline after that age. It is hoped that the application of TRIZ would help elevate the level of creativity in later years.

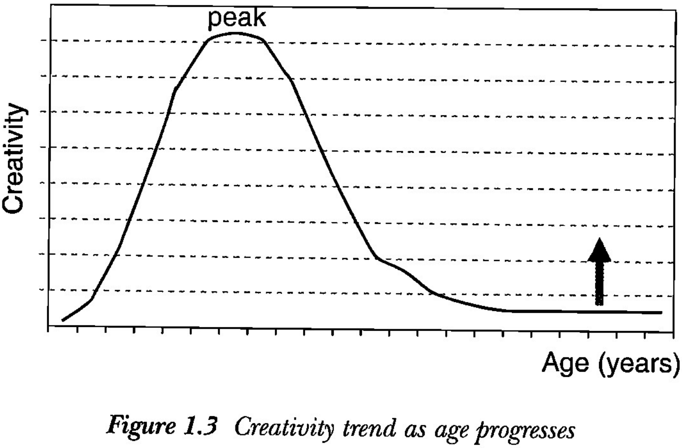


Figure 1.3 Creativity trend as age progresses

Psychological Inertia in the form of links between the brain and experience or knowledge from one's field of study comes into play when solving problems. This Psychological Inertia can limit innovation or creativity in developing new or alternative solutions; which ultimately prevents the system from achieving Ideality. The application of TRIZ is to provide systematic brainstorming whereby generic solutions are provided to guide a brainstorming group to consider possibilities of application to solve their problem.

CHAPTER 2

TRIZ Problem Solving Process

Plan-Do-Check-Act

As you can see in Figure 2.1, although the ideal approach to problem solving is to do the standard Plan-Do-Check-Act process flow with equal emphasis, the actual situation is that we Plan a little, Do a lot, Don't check; and Do lots of "fire-fighting" to contain a problem and fix the root cause. The disparity between the ideal versus actual case is attributed to the fact that the average human brain is much happier in "doing", i.e. executing potential solutions, rather than "planning", i.e. understanding what the problem is. TRIZ uses a detailed approach through the various tools in identifying and understanding what the problem is.

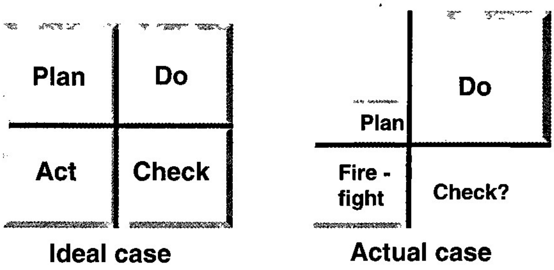


Figure 2.1 Plan-Do-Check-Act – Ideal versus Actual case

Let's consider a typical problem solving process and see how TRIZ can complement and enhance some of the key process steps.

Typical problem solving process

A typical problem solving process (Figure 2.2) consists of:

(a) Problem definition i.e. determining what the problem is
(b) Root cause identification i.e. pinpointing root of the problem
(c) Solution generation i.e. determine right solution to fix root cause
(d) Solution implementation i.e. implement fix
(e) Evaluation i.e. check to ensure solution has fixed root cause
(f) Refine solution if needed i.e. iterate solution if root cause is not completely fixed or if other problems arise (secondary problems)

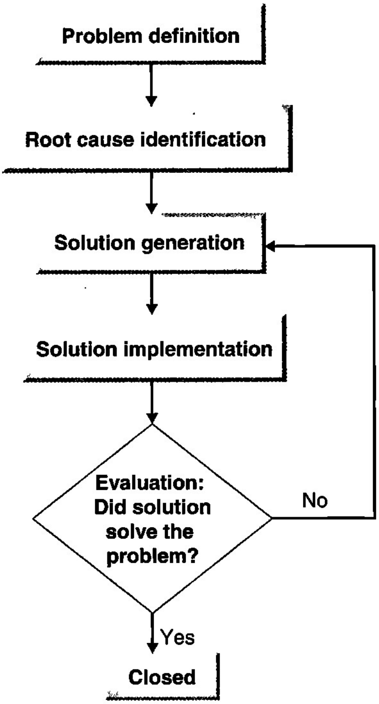


Figure 2.2 Typical problem solving process flow

TRIZ way of problem solving

The strategy in which TRIZ resolves problems is atypical of a normal problem solving process. A typical problem solving is to move from a specific problem directly to find a specific solution. However, there are many instances where this approach may not work due to contradictions or conflicts which prevent good solutions from being generated. In most cases, the solution using the normal problem solving process will be in the form of a compromise or finding a "sweet spot". The TRIZ problem solving process which works towards resolving contradictions or conflicts while providing an inventive solution is as shown in Figure 2.3 (Mann, 2002).

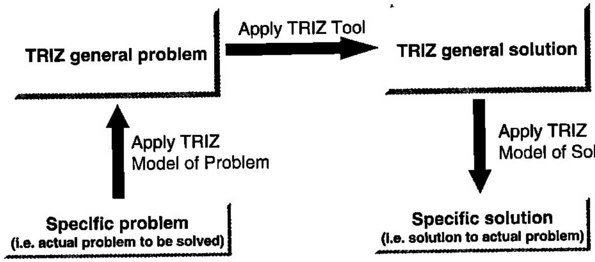


Figure 2.3 TRIZ way of problem solving

A specific problem can be generalized into a TRIZ general problem (e.g. Engineering Contradiction, Physical Contradiction, Function Model, Substance-Field Model) which basically models the problem (GEN3, 2006). Based on this general problem (or Model of Problem), TRIZ provides the Tool to resolve this (e.g. Contradiction Matrix, System of Standard Inventive Solutions). The user still has to take the final step of determining the type of specific solution needed based on the suggested TRIZ general solution (e.g. 40 Inventive Principles, 76 Standard Inventive Solutions). This would be the Model of Solution where e.g. a specific Inventive Principle or specific Standard Inventive Solution is selected and solution is generated to solve the specific problem.

The Model of Problem can be illustrated in Figure 2.4 as modeling the problem in a certain format e.g. finding the resistance given a 5 Volts power supply with 1 Amp of current flowing through the circuit. In order to find the resistance, apply the Laws of Electricity which serves as a Tool to solve the problem. The Model of Solution is 5 ohms resistance.

Model of Problem	Tool	Model of Solution
5 Volts, 1 Amp	Laws of Electricity	5 ohms

Figure 2.4 Example of Model of Problem, Tool and Model of Solution

The TRIZ way of problem solving has a similar analogy especially with mathematical problem solving. Figure 2.5 shows the methodology to obtain the gradient of a straight line. The problem can be easily solved by equating the coordinates to a standard (x,y) format and computing the gradient through a standard formula.

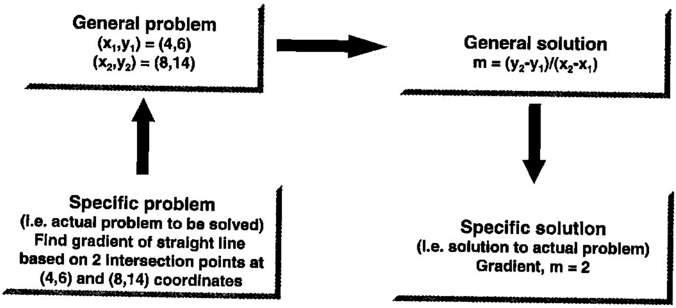


Figure 2.5 TRIZ problem solving - Analogy to mathematics

Based on the typical problem solving process as described earlier in Figure 2.2, TRIZ is able to complement and enhance the 1st 3 steps of the problem solving process.

(a) Problem definition i.e. determine what the problem is
(b) Root cause identification i.e. pinpoint root of the problem
(c) Solution generation i.e. determine right solution to fix root cause

We have found that TRIZ is particularly useful in helping engineers who are working on either technology development or manufacturing sustaining in terms of generating innovative solutions as TRIZ is very well established in dealing with physical, mechanical and thermal related problems. Interestingly, we have also found successful applications of TRIZ in other non- physical, mechanical or thermal fields which include people management (Mann, 2004), information technology, building and construction (Yeoh et al., 2008a).

In the manufacturing sustaining projects, breakthrough solutions were able to be generated even though the problem could have been around for more than three years. And why weren't the problems solved prior to TRIZ? Psychological inertia is one of the key reasons as it limits "out of the box" or innovative thinking. The systematic approach used in TRIZ to provide innovative solutions has resulted in a "systematic innovation". The following chapters will detail out the TRIZ problem solving process.

CHAPTER

3

Overview of TRIZ Models & Tools

TRIZ Models and Tools

The TRIZ process flow for solving a particular problem is detailed in Figure 3.1.

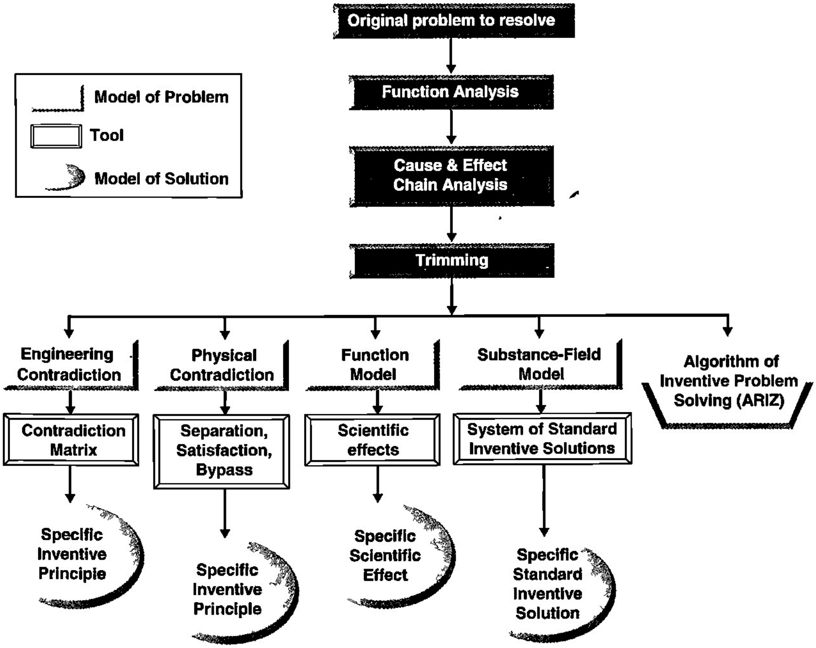


Figure 3.1 TRIZ problem solving map

You start off with the original problem to resolve. Examples include equipment low yield or low productivity, high failure rate for a certain failure mode, high equipment downtime. The original problem is normally at a high level and does not really provide enough details to solve the problem. In some cases, this is initially thought to be the issue which prevents a particular system from performing the desired function. In order to distill the problem to the next level, 2 key steps are performed.

The first step is to perform *Function Analysis* on the identified system. Hierarchically, we have the Supersystem, System and Subsystem. Function Analysis helps to clearly identify the *Engineering System* (which is the System), along with detailing the components within the Engineering System (called the Subsystem), along with its interaction with the Supersystem. These Supersystem components can influence the Engineering System although they were not designed as part of the System. There have been situations where the owner of the Engineering System may not necessarily understand the interactions or actions between the Subsystem and Supersystem components and further investigation and studies are needed before proceeding further. If the Function Analysis is rigorously done and is detailed enough, the subsequent process steps would be much easier. Details are in Chapter 4.

The second step is to perform Cause & Effect Chain Analysis. The Cause & Effect Chain Analysis will help identify the fundamental root cause(s). These fundamental root causes are essentially the root cause(s) of the Engineering System problem which needs to be resolved. These are then worked on by the process called Trimming, followed by the use of the various TRIZ tools.

These TRIZ tools start off with the Model of Problem (e.g. Engineering Contradiction, Physical Contradiction, Function Model, Substance-Field Model), followed by the Tool (Contradiction Matrix, Separation/Satisfaction/Bypass, Scientific Effects, System of Standard Inventive Solutions), and Model of Solution (Specific Inventive Principle, Specific Scientific Effect, Specific Standard Inventive Solution). There are also other methods/tools which integrate the Model of Problem, Tool and Model of Solution i.e. ARIZ (Algorithm of Inventive Problem Solving).

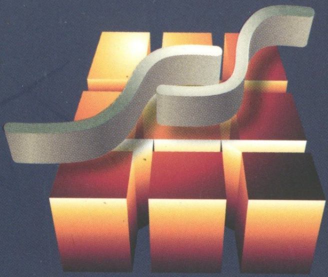
The following is a brief introduction and overview of the various models and tools. Their detailed descriptions are in subsequent chapters.

Model of Problem

Developing the *Model of Problem* is one of the most important steps towards solving a problem which has a contradiction. The contradiction can be modeled in the form of a function whereby a useful function may give rise to ineffective, excessive or harmful functions. This can be narrowed down using Engineering Contradiction to two characteristics or parameters i.e. if one parameter improves, another parameter worsens. The Engineering Contradiction can be refined further into a Physical Contradiction whereby the focus is on one controlling parameter. The derived solution is normally more comprehensive and effective, as Physical Contradiction is more detailed than Engineering Contradiction. In addition, the Substance-Field Model can also be used. The Substance-Field Model focuses on the area of interest called the Zone of Conflict. By doing so, the Substance-Field Model is simplified normally to 2 substances and 1 field. Notice the change from functions or actions (in Function Model) to fields (in Substance-Field Model).

Tool

The Contradiction Matrix (or Altshuller's Matrix) is used to generate potential Inventive Principles based on the improving and worsening parameters from the Engineering Contradiction. As for Physical Contradictions, there is an algorithm in terms of a set of questions to guide the user to determine which option to use to solve the contradiction. Once the option is chosen, a list of Inventive Principles can be referenced as potential solutions. As for the Substance-Field Model, there is a System of Standard Inventive Solutions available which allows users to refer to, once the Substance-Field Model has been determined to be Incomplete, Ineffective, Harmful or Measurement & Detection. The user can also reference libraries of Scientific Effects provided by software vendors or through research and development.



TRIZ

Systematic Innovation in Manufacturing

"Lots of people have good ideas; too few actually turn these ideas into reality that generates value, particularly in a very controlled environment such as in manufacturing. Systematically applying TRIZ is a sensible and powerful way to do exactly that. Consequently, this book is a major contribution to the manufacturing community, especially in this swiftly moving and highly competitive manufacturing atmosphere in which we are all now living."

Eugene S. Meieran,
Ph.D., Intel Senior Fellow
Member of National Academy of Engineering

"The book can serve as a good learning material for basic TRIZ. It also briefly covers some more advanced tools and describes TRIZ general philosophy. The main value of the book is in numerous examples and case studies from the manufacturing area that will be interesting for TRIZ practitioners."

Sergei Ikovenko,
Dr.-Eng., Ph.D., TRIZ Master, Professor (MIT)
Vice President of the International TRIZ Association

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