Innovation on Demand

New Product Development Using TRIZ

Victor Fey and Eugene Rivin

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This book describes a revolutionary methodology for enhancing technological innovation called TRIZ. The TRIZ methodology is increasingly being adopted by leading corporations around the world to enhance their competitive position. The authors explain how the TRIZ methodology harnesses creative principles extracted from thousands of successful patented inventions to help you find better, more innovative solutions to your own design problems. You'll learn how to use TRIZ tools for conceptual development of novel technologies, products and manufacturing processes. In particular, you'll find out how to develop breakthrough, compromise-free design solutions and how to reliably identify next generation products and technologies. This explains the book title. Whether you're trying to make a better beer can, find a new way to package microchips or reduce the number of parts in a lawnmower engine, this book can help. Written for practicing engineers, product managers, technology managers and engineering students.

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Preface

This book describes a powerful methodology for systematic technological innovation called TRIZ (pronounced *treez*). TRIZ is the Russian acronym for the Theory of Inventive Problem Solving (***T****eoriya* ***R****esheniya* ***I****zobretatelskikh* ***Z****adach*). The book acquaints the reader with basic tools of TRIZ and their applications to the conceptual development of novel technologies, products, and manufacturing processes.

This book is principally intended for practicing engineers whose responsibilities run the gamut from R&D activities, to design, to shop floor administration. Engineering students will also benefit from its contents. The book describes the vital role of TRIZ in the process of technological innovation. Technology managers who use TRIZ approaches often find strategic opportunities that non-users tend to overlook. They capitalize on these opportunities by developing new products and processes, as well as novel services and organizational structures.

TRIZ originated in the former Soviet Union, where it was developed by Genrikh Altshuller and his school, beginning in 1946. TRIZ was used extensively in the Soviet space and defense industries to enable engineers to overcome difficult technological challenges within an inefficient economic system. It was virtually unknown in the West, however, until a translation of one book by Altshuller was published in 1984 (*Creativity as an Exact Science*, by Gordon and Breach, New York). While the book initiated a few devotees to TRIZ, a poor translation minimized its impact.

In 1991, a TRIZ-based software package, developed by the Invention Machine Corporation, was demonstrated in New York and commercially launched. Although the software attracted significant interest, it was, essentially, only a series of illustrated problem-solving analogies that failed to reveal the thought process required for the effective application of the methodology itself. Since the software's users were by and large unfamiliar with the thought processes behind TRIZ, they were unable to fully utilize the power of this methodology.

Throughout the 1990s, small consulting groups began to appear in the West, usually founded by immigrants from the former Soviet Union. Their principals were experienced TRIZ practitioners. Many of those pioneers were students and collaborators of TRIZ's founder, Genrikh Altshuller. Those groups were solving problems for their client companies and training customers in TRIZ fundamentals. As a result of these efforts, leading corporations in the U.S. and overseas have reported significant benefits from using TRIZ (e.g., see Raskin, 2003).

In 1993, after modifying the approach to TRIZ training adopted in the Soviet Union to better suit American audiences and after offering several successful public seminars, the authors started a four-credit course on TRIZ at Wayne State University in Detroit. Students appreciated the course immediately. The experiences accumulated through the course instruction, as well as knowledge gained from training and consulting projects for industrial clients in the US and overseas (through The TRIZ Group founded by the authors), convinced us that a comprehensive text-book on TRIZ principles was necessary.

This book covers the basic concepts and tools of contemporary TRIZ. The only criterion for including a subject was whether it was essential for the successful application of the methodology. Every notion, method and technique is illustrated by real-life examples gleaned from different areas of technology. Many examples are based on our own inventions, both patented and otherwise, made with the help of TRIZ. Most chapters end with a set of problems and exercises that give the reader an opportunity to sharpen his or her understanding of the earlier described material.

Today's TRIZ contains numerous problem analysis and concept generation tools, not all of them well formalized. In this book, we primarily describe the most formalized tools, such as the ideality tactics, the separation principles, the sufield analysis, the Standards, ARIZ, and some others. Major non-formalized, but still powerful tools of TRIZ, such as the system operator, the size–time–cost method, and the "smart little people" method are described in other books (e.g., Altshuller, 1994, 1999; Mann, 2002).

This book addresses the application of TRIZ to two basic activities which engineers and scientists in a technology-based company may be responsible for: (A) The improvement of existing technologies, products and manufacturing processes ("problem solving"); and (B) The development of next-generation technologies, products and processes ("technological forecasting"). TRIZ has proven to be greatly beneficial for both these activities.

Proliferation of TRIZ in the West started from marketing Invention Machine™ software. Now there are several software products on the market that claim computerization of TRIZ. Usually, these products contain vast knowledge bases of various TRIZ techniques and physical effects, as well as some problem formulation tools. They also contain libraries of good design concepts gleaned from various engineering domains. In our experience, engineers trained in TRIZ to the degree of deep understanding of its principles and thought processes, can be helped by these products. This can be compared with other computer-assisted engineering activities. Extremely powerful software packages for finite element analysis (FEA) can treat a huge variety of stress/strain problems. The results, however, can be right or wrong depending on the model of the analyzed problem that was constructed by FEA software's user. So, one must be good in strength of materials and/or theory of elasticity to generate adequate FEA results. The same can be said about CAD packages. Although these give many prompts to the operator, it is hard to imagine somebody without a mechanical (or electrical) design background and education making a good set of design drawings.

The book is organized in six chapters and five appendixes. Chapter 1 is an introduction that demonstrates the need for systematic innovation. Chapter 2 describes TRIZ tools for resolving conflicts between competing design requirements. Application of these tools results in compromise-free design solutions. Chapter 3 introduces a TRIZ substance–field approach used for modeling physical interactions in technological systems. Chapter 4 describes the Algorithm for Inventive Problem Solving, the most powerful problem analysis and concept development tool of TRIZ. Chapter 5 describes the foundation of TRIZ – the laws of technological system evolution. Chapter 6 outlines a comprehensive approach for guided development of next-generation products and manufacturing processes based on the laws of evolution.

Appendix 1 contains a brief biography of Genrikh Altshuller, the creator of TRIZ. Appendix 2 outlines an alternative TRIZ approach to resolving conflicts. Appendix 3 expands upon the subject of the substance–field modeling approach, introduced in Chapter 3, and describes the 76 Standard Approaches to Solving Problems and the algorithm for using these Standards. Appendix 4 presents an overview of the application of TRIZ to resolving management (i.e., non-engineering) challenges. Appendix 5 contains a glossary of TRIZ terms.

For a comprehensive understanding of contemporary TRIZ, reading of the whole book is desirable. As with many textbooks, however, a selective reading may satisfy some individuals not so much concerned with applications of TRIZ to specific problems but rather interested in assessing its overall potential. Those readers who are mostly interested in the problem-solving tools of TRIZ, should pay more attention to Chapters 2–4. The readers with the primary interest in the management of technology innovation and development of next-generation technologies will mostly benefit from Chapters 5 and 6.

We know that this first TRIZ textbook is not perfect and are grateful in advance for any constructive comments and criticisms.

1 Introduction

Technology is as old as mankind. Myriad small and large innovations have shaped the world, and are molding the future of civilization. The prevailing majority of these innovations have been developed haphazardly; their creators have not used any organized approach to finding new ideas. Despite the great past achievements of a random approach to innovation (the wheel, the automobile, the radio, the airplane, the computer, antibiotics, to name just a few), that approach has become increasingly inefficient in today's fiercely competitive marketplace. This chapter shows the principal shortcomings of *random innovation*, and the need to replace it with a method of *systematic innovation*.

1.1 Product development process

Every new product – whether the "product" is a technology, a device or a production process – originates from a new concept. To become a product, a concept must be generated, then evaluated and, finally, developed. This flow of activities constitutes the *product development process* (*PDP*) (Fig. 1.1).

The process begins with the recognition of a *need*. Then, the designer must transform this need into a *clearly defined problem*, or a set of problems. The output of this stage is a problem(s) statement accompanied by a list of various constraints (e.g., performance specifications, manufacturing limitations, economic conditions, statutory restrictions, etc.).

In the next phase, various *conceptual solutions* to the problem(s) are generated. Here, the most important *decisions* are made which bring together engineering, production, and commercial aspects of the problem.

In the following phase of the process, the generated *concepts* are evaluated against various criteria, and the most promising ones are selected for designing a *prototype*. The prototype is then built and *tested*. During this process, necessary corrections are usually made to the conceptual solution.

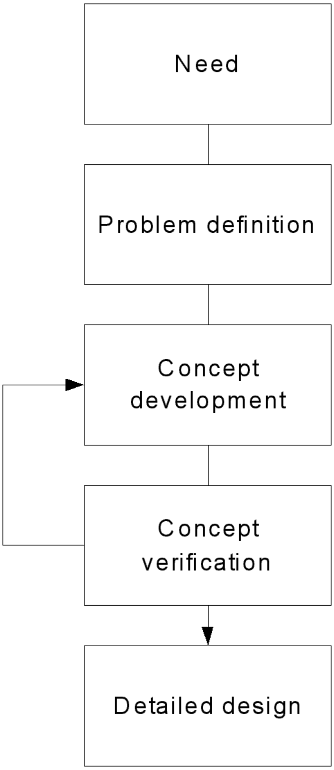

Fig. 1.1. Phases of a typical product development process.

Finally, in the *detail design phase*, the design is fully developed and the dimensions of all the components are determined, the materials specified, etc. Then, detailed drawings are produced.

Modern engineering sciences possess an extensive arsenal of powerful analytical methods and software tools for the efficient evaluation of new concepts, and the development of these concepts into successful processes or product lines. This arsenal has a centuries-long history of gradual evolution.

In the past, there was no other way to test an attractive idea, than to practically try it. Almost all basic chemical compounds have been obtained through a tremendous amount of blind testing by alchemists. Even Thomas Edison, while working on the design for the incandescent bulb, would perform over 6000 experiments with a vast variety of materials before settling on a satisfactory filament.

As science and technology continue to develop, the boundary between what is feasible and what is not becomes better understood. Many products, processes and their environments can, today, be reasonably well simulated. Nowadays, the chemical industry brings numerous new compounds to market every year. This could not be possible without well-developed theoretical methods for rational analysis and synthesis of proposed formulations. While working on a problem, an engineer can filter out weak concepts by using knowledge obtained from basic education, from his or her experiences and those of his or her predecessors, from information in patent and technical literature and, of course, by using computer-based systems such as computer-aided design (CAD), computer-aided manufacturing (CAM), finite element analysis (FEA), computational fluid dynamics (CFD) and others that substantially facilitate the product development process.

1.2 Stumbling blocks in PDP

The least understood and, therefore, often poorly managed first two phases of the product development process are *identification of a need* and *concept development*.

1.2.1 First stumbling block: technology strategy

The first phase – need identification – is, in addition to the market research, also the process of defining a technology strategy. The key question here is (or should be): "*What is the next winning technology to satisfy the potential or perceived market need?*" Answering this question requires a very good understanding of the trends of technology evolution.

In today's fiercely competitive market, manufacturing companies have to gamble their future on the market's next wide acceptance of a product or a technology innovation. They have to figure out what this "winning" innovation will be so as to better allocate adequate financial backing, manpower and other resources. Mistakes in making predictions result in yielding the advantage to competitors.

In 1990, U.S. Steel, then a leader in the American steel market, had a choice of investing in either the conventional hot-rolling technology or in a new compact strip production (CSP) technology. U.S. Steel decided to further improve the well-established, hot-rolling technology. Their competitor, Nucor Steel, funded the development of CSP. Today, Nucor is the leading US steel producer while its formerly formidable competitor is largely marginalized in the marketplace (Cusumano & Markides, 2001).

The two giants of film-based photographic equipment, Kodak and Polaroid, did not recognize the emergence of digital imaging technologies. They each received brutal blows from competitors that pioneered products employing those technologies (Leifer *et al.*, 2000).

Chester Carlson, the creator of xerography, offered his invention to dozens of companies. Each and every one of them turned him down, thus missing out on one of the most successful business opportunities of the twentieth century.

In 1992, start-up Palm, Inc. developed the prototype for its Palm Pilot. The gadget, however, did not excite venture capitalists in Silicon Valley. They saw it as just another personal digital assistant (similar to Hewlett-Packard's Psion, Apple's Newton, and

Windows CE PCs) and refused to fund bringing it to the market (Penzias, 1997). Unable to raise money on their own, Palm became a subsidiary of U.S. Robotics in 1995. Shortly thereafter, the Palm Pilot became hugely successful. Today Palm is again an independent and thriving company offering an impressive array of state-of-the-art handhelds and accessories.

The list of companies that lost their competitive position to more innovative rivals can be easily extended, but so can be the list of successful, "winning" products and technologies that did not have the initial support of management, or of the financial community.

Many business publications and consultants praise market research as the most reliable way to assess the market viability of emerging innovations. While various market research techniques often prove to be very useful for incremental improvements, they often mislead when used to appraise breakthrough innovations.

In the late 1960s, Corning became interested in a promising low-loss optical fiber technology. The company consulted with AT&T – an obvious potential customer – as to the prospects for this technology. AT&T guesstimated that a noticeable need for optical fibers would arise only in the first decade of the twenty-first century. Corning, however, was much more optimistic and set off on the development of this technology. The company had its major commercial success with MCI in the early 1980s (Lynn *et al.*, 1997).

The inability of even the best experts to predict the future of technology is illustrated by the following often-quoted phrases.

- "Heavier than air flying machines are impossible," Lord Kelvin, President of the Royal Society, 1885.
- "Everything that can be invented has been invented," Charles H. Duell, Director of the US Patent Office, 1899.
- "Who the hell wants to hear actors talk?" Harry Warner, Warner Brothers, 1927.
- "There is a world market for maybe five computers," Thomas Watson, Chairman of IBM, 1943.

A more recent example: Bill Gates could not foresee the rise of the Internet.

Hindsight is always 20/20, but how can we make sure that the products or technologies being pursued now are the ones that the market will need? How can we choose the best solutions? What are the criteria that will allow us to select the most promising concepts? Conventional approaches to the identification of next-generation winning products and technologies cannot provide reliable answers to these questions. The TRIZ perspective on these questions is addressed in Chapters 5 and 6.

1.2.2 Second stumbling block: concept development

Today, just as for many centuries, novel ideas in engineering (as well as in other areas of human activity) are mainly produced by the *trial-and-error* method. The essence of this method is a persistent generation of various ideas for solving a problem. There are

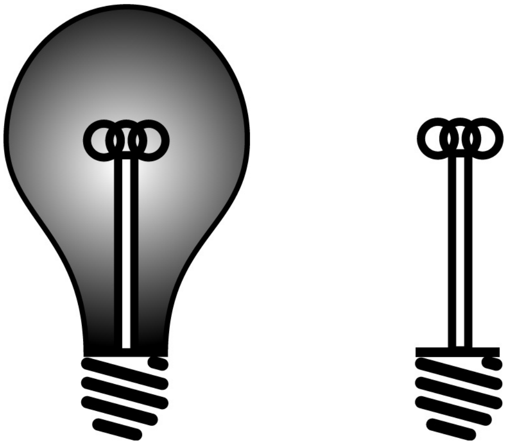

Fig. 1.2. Absent glass cannot break.

no rules for idea generation, and the process is often stochastic. If an idea is weak, it is discarded and a new idea is suggested. The flow of ideas is uncontrollable, and attempts (trials) are repeated as many times as is needed to find a solution.

Although seemingly random, most trials have a common attribute: they are more numerous along a so-called vector of *psychological inertia.* This inertia is determined by our cultural and educational backgrounds, previous experiences and "common sense." More often than not, psychological inertia is created by a deceptively innocuous question, *"How?"* (e.g., "how to fix this problem") that nudges the problem-solver toward traditional approaches, dims the imagination and is a key hurdle on the track to the best solution. In fact, the best solution often lies elsewhere, in territories that our common sense deems useless.

Example 1.1

A classic example relates to the psychological inertia of "rocket scientists," supposedly the most educated, sophisticated and innovative of all engineers. In the 1970s, the United States and the Soviet Union fiercely competed in the area of Moon exploration. Unable to afford the costs of an Apollo-like project for landing astronauts on the Moon, the Soviet Union decided to launch an unmanned lunar probe to deliver an autonomous vehicle to the back (dark) side of Moon's surface. The vehicle was to transmit TV pictures of that not-yet seen side to Earth. The incandescent light bulb was found to be the best light source, however existing light bulbs would not survive the impact of landing on the lunar surface. Even the most durable bulbs, those used in military tanks, cracked at the joint between the glass and the socket during tests.

A major effort was started to figure out *how* to strengthen the glass bulb. The situation was reported to the director of the whole Moon-landing project. His first question was: "*What* is the purpose of the bulb?" The answer was obvious – to seal a vacuum around the filament. However, there is an abundance of perfect vacuum on the Moon! This simple question solved the problem – no glass bulb was needed (Fig. 1.2).

Table 1.1. *Muffler alternatives*

Type of muffler	Cost ($)	Noise level (dB)	Back pressure (psi)
A	60	79	7.65
B	90	79	7.40
C	60	82	7.40
Targets	60	79	7.40

Example 1.2

A team of seasoned automobile designers was developing an exhaust system for a new truck. Specifications contained various performance and economic criteria, the most important ones being the noise level, back pressure (affecting the engine's efficiency) and cost. All of these attributes are largely influenced by the specific design of the muffler. There was no commercially available muffler that would meet all the target criteria, so for several months (!), the design team brainstormed the solution space, searching for an adequate muffler design.

Various solutions on *how* to improve the muffler designs were proposed, but none complied with the targets. Three alternative muffler designs A, B, and C that offered the parameters closest to the specifications were identified (Table 1.1). Only the very expensive muffler B had an acceptable technical performance, but its cost was excessive by a large margin. The new truck had to be launched, and budget-breaking muffler B was grudgingly approved.

Relief came unexpectedly from two young co-eds who, at the time, were taking the TRIZ class at Wayne State University. Analysis of the situation by TRIZ methods lead them to question *what* had to be achieved. The existing noise regulations address not the system components (muffler), but the noise exposure of a person on a sidewalk (Fig. 1.3a). Accordingly, the co-eds suggested adopting muffler C, but modifying another part of the exhaust system so as to meet the noise-level specifications. The solution was very simple and elegant.

While the original exhaust system was equipped with a straight tail pipe, essentially aiming towards the microphone, the co-eds bent the end of the pipe downward (Fig. 1.3b); now the sound, produced by the exhaust, does not affect the by-stander (and the measuring microphone), but is deflected to the ground.

Experiments showed that this solution met all the required criteria, and it was immediately implemented.

The fact that such simple solutions in both examples were missed, illustrates the obstructing power of psychological inertia.

The trial-and-error method results in valuable time being wasted when searching for solutions to difficult problems. Damages from the hit-and-miss approach are associated

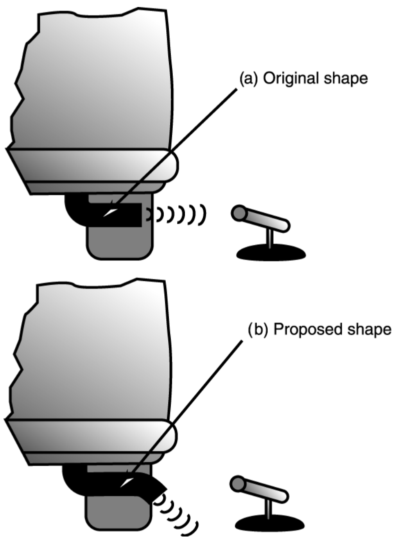

Fig. 1.3. Exhaust system modification.

with lost competitiveness and a waste of manpower and financial resources. Nor does it help that the random generation and selection of concepts fails to provide for the experience gained by solving one problem, and utilizing that experience to solve other problems.

Accordingly, the need for improving the concept generation process has long been necessary (some pre-TRIZ methods for creativity enhancement are described in Appendix 2).

1.3 TRIZ

The *Theory of Inventive Problem Solving* (*TRIZ*), developed by Genrikh Altshuller (Altshuller and Shapiro, 1956; Altshuller, 1994, 1999), states that while the evolution of technology is apparently composed of haphazard steps, in the long run it follows repeatable patterns. These patterns can be applied to the systematic development of technologies – both to solving product design and production problems and to the development of next-generation technologies and products.

TRIZ deals not with real mechanisms, machines and processes, but with their models. Its concepts and tools are not tied to specific objects and, therefore, can be applied to the analysis and synthesis of any technology regardless of its nature. TRIZ also treats all products, manufacturing processes and technologies as *technological systems* (more on that in Chapter 2).

The premise of TRIZ is that *the evolution of technological systems is not random, but is governed by certain laws.*