Four Types of Problem Solving

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Introduction

There is no shortage of problems today. Social problems, business problems—every organization in every sector encounters problems daily that they confront, avoid, or fail to even recognize. Naturally, we want to solve each problem we face. There are many books and training classes on problem solving and you probably have read many of the books and attended such training. But problem solving as a skill seems stuck in first gear or, worse, to have slipped into reverse. That's why we think it's time to step up and help others understand and coach the art and science of effective problem solving.

Why Problem Solving?

Problem solving is arguably the most fundamental of human activities. We breath, we eat, we sleep. Breathing and sleeping just happen. Then we get hungry or we might get cold. That's our first problem to solve. To be human is, quite literally, to solve problems.

So the question of how to go about solving problems effectively is fundamental to the reality of our daily existence. And it is certainly fundamental to what it means for us humans as we organize ourselves for industrial endeavors. Any company pursuing any form of improvement is well-advised to consider deeply this topic of problem solving. Without question an organization with only pockets of problem solving ability will struggle in the long run. An organization with an army of problem solvers is much better suited to face the challenges of the competitive marketplace. More powerful yet is the company that has problem solving capability embedded throughout the organization. For this book that's our starting point—problem solving as part and parcel of industrial endeavor.

Industrial problem solving has been around as long as industry. As seasoned problem solvers often note, there is little new under the sun when it comes to problem solving. Logic, critical thinking, mathematics, and quality tools have played large roles in the development of modern problem-solving. The industrial revolution was, in itself, a problem-solving effort on a grand scale in terms of how to be more productive. Humans came to live in ever-larger communities, producing goods that both satisfied demand and created more of it. In turn, demand for ever greater efficiency to make things better led directly to the need for problem solving on a very practical level.

What Are Problems and What is the Problem with Them?

We have a problem with the very word problem. A *problem* sounds like a very bad thing indeed. According to *Dictionary.com*, a problem is "a matter involving doubt, uncertainty or difficulty; a question proposed for solution or discussion; or, in mathematics, a statement requiring a solution".

Lean thinking on the other hand defines a problem simply as the gap between the way things are and the way we would like them to be. Recognizing problems as welcome opportunities to improve any situation is arguably the most important charracteristic of a continuous improvement organization. Hiding problems is, conversely, the most intractable trait of any organization that wishes to improve. As we like to say, "No problem is a problem!"

But no less an authority than the Oxford dictionary gives us this definition of a problem: "A matter or situation regarded as unwelcome or harmful and needing to be dealt with and overcome". Contrast this with the middle English definition (from old French, Latin and Greek) which defined a problem simply as a riddle or question for discussion. Ah—that we could return to such simpler times!

So now we have this term—problem—that represents a concept that is essential to lean thinking but that is loaded with negative, even anti-lean, nuance. What to do? One option: use alternative terms. So some choose to refer to problems as "opportunities". But, an opportunity implies a situation in which taking action is optional. But, when our product doesn't' work as intended for a customer—when the brakes don't stop the car – taking action is no option: it is mandatory!

So, in this guide, we will call a problem a problem with the aim of making us all better problem solvers.

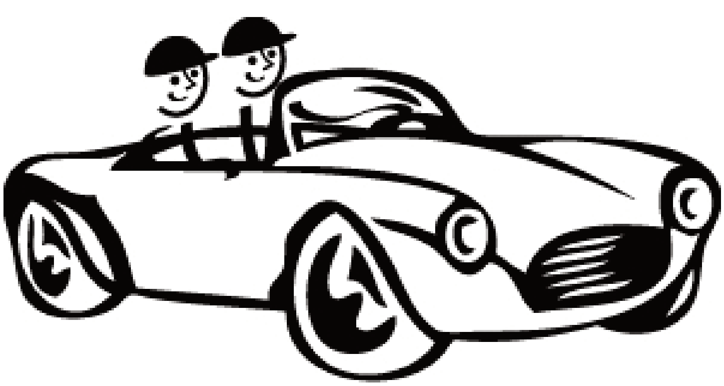
Why a Book about Problem Solving?

The purpose of the book is to address a very big concern. There is much noise in the lean community and beyond that creates confusion around this important topic of problem solving. What is a problem? How do we go about addressing them? There are many methods and models of problem solving out there, and many of them may have their place depending on the circumstance. The intent of this book is to provide a framework, a context, to help serious problem solvers think about the picture of problem solving and continuous improvement in a holistic way.

There's not just one method that is best for all problems. But no "one best way" does not mean there is not some basic thinking—a framework—that can make sense of the many ways that problems come at us. So, what does lean thinking, or Toyota thinking, have to say about all that? That's the promise of this book—it's not a *how-to-do* book so much as a *how-to-think* book.

With this book we present a comprehensive body of problem-solving knowledge in a format that we hope is easy for beginners to grasp yet useful even for advanced practitioners. We have several specific goals in mind:

- **A reference guide**: This is an "owners manual" for individuals and teams working at solving problems. In every new car, for example, you will find an owner's manual in the glove box. You don't need to look at it every day, but when you are in trouble, a reference guide is a wonderful thing. Think of this as your quick and handy problem-solving owner's manual.



- **Minimize problem-solving errors:** If we problem solve to resolve errors, shouldn't we also do the same with the problem-solving process itself? As we observe the current state of problem solving in general, we see certain mistakes being made over and over again. Some of these are simply goofs that are a part of the normal learning process and contribute to building up our skill level. No one gets everything right the first time, and learning from mistakes is a great way to learn. However, other errors and mistaken assumptions exist that are needless, wasteful, and even harmful. With this book—by outlining the types, examples, major steps, key points, reasons why, and some coaching tools for problem solving—we wish to mitigate some of the confusion and some of the errors we are all prone to make.
- **Develop problem-solving skills:** Problem solving must be a core part of the DNA of any aspiring lean organization. It is fundamental lean thinking for anyone at any level to think critically about work and solve problems on the job. All skill-intensive endeavors require practice and honing of technique over time—the same is true for the skill of problem solving.
- **Boost effectiveness of improvement efforts:** We hope this guide can speed you along your improvement journey. That's really what it's all about, right? Moving from any current state to an improved state is a transitional journey by definition. Problems will arise, and it is our duty to solve them effectively and efficiently as we create better value-creating processes for customers.

What's in this Book?

The contents of this guide borrow quite heavily from Toyota Motor, where problem solving is truly core to the company's very DNA. Employees who remain with Toyota long enough eventually learn the basic methods or at least the essential thinking that is presented here. In this book, we'll highlight basic skills to be mastered. We'll also present some skills that go beyond the basics.

Problem solving is an individual skill-related developmental activity and a critical piece of the respect-for-people that Toyota embraces and that we insist on for all lean practitioners. However, as the experienced reader will be well aware, problem solving in general has many roots that go back in history, well beyond the domain of Toyota-developed knowledge. So we have organized the chapters and progression of this book to provide both a backbone and breadth of problem-solving ideas and concepts as well as tactical tools to solve the problems you encounter.

In this book you will find:

- **Problem-solving influences:** Like the laws of physics, many of the problem-solving concepts developed in past have been proven out by decades of efficacy and are still highly applicable today. They also are embedded in more modern problem-solving approaches, which you will find in Chapter 1. This summary of problem-solving influences will help you understand and better leverage all problem-solving tools.

- **Types of problem solving:** There are essentially four different types of problems that require four different types of problem solving. We explain the four types in Chapter 2, and in subsequent chapters offer examples of each and describe their unique application:

  - *Troubleshooting*: a reactive process of rapidly and often temporarily fixing problems.

  - *Gap-from-standard problem solving*: solving problems in relation to existing standards or conditions.

  - *Target-state problem solving*: achieving new, better standards or conditions (i.e., kaizen or continuous improvement).

  - *Open-ended problem solving*: tackling problems when we may not even know exactly where we're headed, sometimes in pursuit of a vision (new products, processes, services, or systems) and often resulting in innovations that we didn't even anticipate.

- **Seven steps common to solving most problems:** Two of the four types of problem solving—gap-from-standard method (Chapter 4) and the target-state method, which together can help us solve most of our business problems—rely on seven common problem-solving steps. So we dig a bit deeper into the problem-solving routines of these two types, helping you to work through each step as you solve real problems in your organization.

Who is Your Guide for this Deep Dive into Problem Solving?

Your guide for this deep-dive into problem solving is Art Smalley. Art has immersed himself in the intricacies of problem solving since 1988, when he joined Toyota at its Kamigo Engine Plant in Toyota City, Japan. At Kamigo, where Taiichi Ohno was plant manager and conducted many of his famous experiments that led to the development of the Toyota Production System—problem solving raised to its zenith.

Art learned directly about problem solving from Tomoo Harada, who led the maintenance activities that created the stability that enabled Ohno's innovations in flow to succeed on a large scale. Without basic stability: no just-in-time. Without problem solving: no basic stability.

Art's study of problem solving continued from there, including apprenticeship with Russ Scaffede and Isao Kato, consulting work with clients including organizations such as Sandia National Laboratories and Donnelly Corp., as well as collaboration with Prof. Durward Sobek, which resulted in an important book for the lean movement and is used as a core resource by many lean practitioners: *A3 Thinking*.

How Should you Use this Book?

Even if you have years of problem-solving experience and know many problem-solving approaches, please read this book at least once end-to-end. I'm betting that you will learn things you did not previously know and that you may look at familiar concepts in a new light. Most importantly, please do not merely read it and put it on a shelf, never to be touched again. Pull this book out periodically, whenever you need:

- **Help when you are stuck with a problem:** This book functions like a repair manual. Sometimes we cannot remember every detail or nuance for how to rigorously define a problem or conduct root-cause analysis. At those times we encourage you to refer to this manual and look at the explanatory steps and key points as a refresher and for clarification.
- **A team guide:** We envision teams that are newer to problem solving will use this book as a team facilitation guide. Keep it with you in the team room where problem-solving meetings occur. We have incorporated questions throughout for you and your colleagues to reflect upon and try to answer. This is not a canned "problem solutions" book; no one can solve your problems except you and your team members.

- **A coaching aid:** This guide can be used as a way for people to effectively coach and mentor teams. Simply asking vague Socratic-method type questions is not sufficient for coaching to solve problems and develop problem-solving skills. The problem-solving coaches in Toyota were like good sports coaches or martial arts instructors: they knew the what, how, and why to do activities, and would readily demonstrate the craft when necessary. Such coaching includes asking very specific questions or providing very specific technical insights. This interaction between mentor and mentee is highly situational and dependent upon the learner, the complexity of the situation, and the needs of the organization. We share basic insights for those who will be coaching others through problem solving, knowing that it takes time and effort to develop the skills to address the multitude of coaching situations that arise—no one size fits all in coaching.

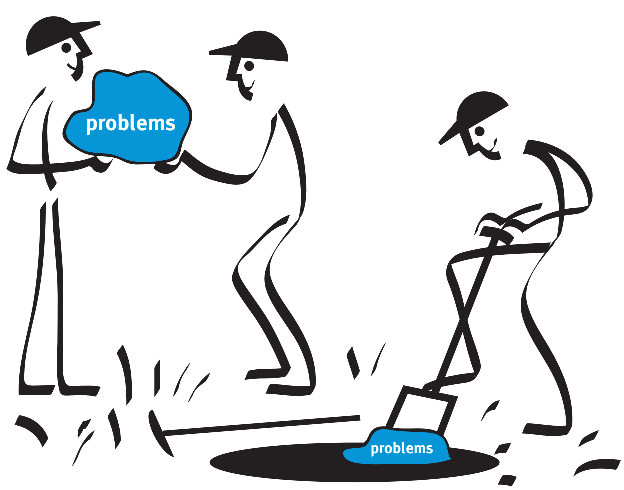
No doubt you will find other uses for this book, and we'd like to hear about them. Our process at LEI includes a feedback loop from end users for us to learn what works, what does not work, and how certain tools actually get applied. We look forward to learning from you how you actually use this guide. We'll need your ongoing help in solving the remaining problems with problem solving.

So, just what are the 4 kinds of problems and problem solving, you ask? Read on.

John Shook
Chairman and CEO, Lean Enterprise Institute
Chairman, Lean Global Network

Having no problems is the biggest problem of all.

— Taiichi Ohno



Four Types of Problems Illustrated with the Five Whys

We often break up the four types problems and problem solving and consider them as separate entities. In reality, the four types are merely lenses through which we can view most any type of problem. Timing, resources, urgency, necessity, and priorities often dictate your response. With some problems it is sufficient to apply troubleshooting methods and then spend remaining time on larger issues that require more attention. Other situations require the immediate use of different problem-solving approaches—gap from standard, target state, or innovation. And certain problems will, over time, require all four types of problem solving.

In this section we will illustrate this point, using Taiichi Ohno's classic example of the *Five Whys* and the personal experiences of Tomoo "Tom" Harada, an engineer who worked for Ohno in Toyota's main engine plant. We will show how the problem —almost always presented as only a Type 2 problem—unfolded over time by the work of different parties using the four different problem-solving methodologies.

Five Whys Background and Original Problem

The following *Five Whys* example is often used in problem-solving discussions to illustrate root-cause thinking required to solve a problem. The basic concept is that when something abnormal occurs, it is important to pursue the causes in depth in order to get to a level where you can prevent it from happening again. This style of thinking does not occur naturally with most people and requires persistent investigation and thinking—thus, the emphasis on *Five Whys* instead of just one or two levels of probing.

The problem involves a machine tool in an engine plant, which stopped working and halted a production line. The *Five Why* sequence below involves first a question and then the corresponding answer:

Situation: A machine tool has stopped working halting production

1) "Why did the machine stop working?"
   - Because the machine overloaded blowing the fuse in the control panel"
2) "Why did the overload condition result?"
   - Because there was insufficient lubrication to the spindle bearing.
3) "Why was there insufficient spindle bearing lubrication?"
   - Because there was insufficient lubrication drawn up by the pump.
4) "Why was there insufficient lubrication draw from the pump?"
   - Because the pump shaft was worn and rattling.
5) "Why was the pump shaft worn?"
   - Because there was no strainer on the lubrication device inlet port, and small metal cutting chips entered the system causing damage.

Conclusion: In order to prevent recurrence of the problem, the simple act of adding a strainer to the inlet port of the lubrication device will, with a high degree of certainty, stop this particular problem from recurring.

The *Five Whys* presents a good example of a Type 2 gap-from-standard approach to solve a real problem. This specific problem-solving tack occurred several decades ago. Now let's consider this example in the context of the four types of problems. In reality, Toyota solved this cutting-chip build up problem in different ways over the years—not just with Type 2. Not every problem due related to cutting chips was solved by adding a strainer inside a tank.

Type 1 Problems—Troubleshooting

The build up of cutting chips is a natural part of the machining process. A cutting tool cuts into the metal of the workpiece and physically creates a "chip" that must then be properly evacuated from the part and the machine. Failure to do so is a recipe for a variety of issues, such as safety/minor cuts, machine downtime, and dimensional quality issues.

In the early days of the Toyota Production System, cutting chips in machining operations was a big problem. So big that it was continually listed on hourly production charts for plan vs. actual production. This represents an historical example of a common Type 1 problem inside Ohno's machine shops. Hourly production totals were often off by a few parts per hour, and the cause was frequently listed as "cutting-chip buildup," which necessitated unplanned cleaning work and machine downtime.

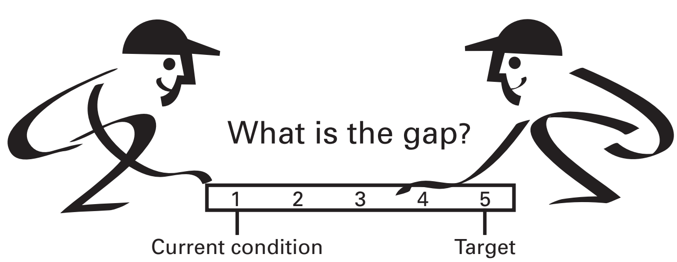
The countermeasure in many cases was to clean the machines at the start, middle, and end of shift using a variety of mechanisms, including brushes, small rakes, manual air blow, and additional coolant flushes. Standardized work and job instruction training was, of course, emphasized as well, but it had only a limited effect on the problem. Cleaning worked in terms of immediate needs, but it did not prevent the problem from recurring; a better approach was needed to get at the real set of underlying issues.

Type 2 Problems—Gap from Standard

As the problem of cutting-chip buildup and contamination continued to occur, supervisors, engineers, and managers were trained to think about the problems in a different, fundamental way—Type 2 problem solving.

Leaders, such as Ohno, began to require that the real root causes of the safety, downtime, and quality issues in machining be addressed more thoroughly. This emphasis on the *Five Whys* occurred in the 1960s in conjunction with structured problem-solving training and execution. Simple daily cleaning, expectation setting, communication, and training were not enough.

Machine-by-machine and problem-by-problem these issues were tackled by Toyota in the engine plant with a root-cause emphasis and goal of recurrence prevention. The root causes of downtime, quality issues, and other abnormalities



were considered more thoroughly. In the famous *Five Whys* example, the simple act of adding a strainer solved this one specific problem, but other problems required different solutions entirely.

Type 3 Problems—Target-State Improvements

The above problem-solving routines solved most cutting-chip issues in the machine shops in a narrow sense: in many cases there no longer was a gap-from-standard problem to be solved, and individual machine performance and production line performance were achieving their daily goals. But structured root-cause analysis with convergent thinking patterns (Type 2) wasn't the only way to study the problem. The bar for annual improvements within Toyota also had moved higher, requiring better performance as well. Type 3 target-state problem solving became both necessary and desirable for further improvement.

Target-state improvement involves first principles of flow, takt time, built-in quality, safety, reliability, and an attitude of mental challenge. For example, 100% safety, 100% quality, and 100% uptime with a shorter lead time are target-state aspirations. The act of cleaning cutting chips was viewed as wasteful in nature and also not respectful of the human operator. Management and engineering looked at the cutting-chip issue from an "aru beki sugata" or "ideally how should this process work" point of view. Eliminating cutting chips is impossible, but one can still consider what is the ideal size of the chip (e.g. smaller is better), how it is formed, how it flows away from the part, how the machine is guarded, and how the operator is protected.

This line of inquiry led to many instances of trial-and-error and improvement suggestions over the years inside of Toyota machine shops. Improved control of machine feeds and speed, with an emphasis on tooling and chip formation, led to some improvements. Improved use of coolants, nozzle pressure, nozzle location, nozzle angle, etc. contributed as well. Modifying the internal bed-plate angle and fixture portions of the machines also helped cutting chips flow away more effectively, greatly reducing the need for cleaning. Hydraulic, coolant, and lubrication tanks were sealed better as well. Improved usage of machine guarding and safety switches and doors contributed to greater safety.

Note that with Type 2 problem solving the cutting-chip problem was solved outside of the machine, away from the point of generation by adding a strainer to an external tank. In the subsequent decades the problem was better resolved by managing the chip at the point of formation, which Toyota often calls "cutting-point management" or "tooling-point management." This also included special routines for tool setting, tool cleaning, tool-holder cleaning, setup and confirmation, and tooling programs (i.e., standardized work for the cutting program). This approach represents a Type 3 solution or improvement pattern. The focal lens for problem consideration was directed at an ideal or target state. This more challenging consideration did not let the cutting chip escape from the machine, instead controlling it inside at the source and at a more fundamental level. This represents a classic example of kaizen and divergent creative thinking, in subtle contrast to Type 2 convergent root-cause analysis.

Type 4 Problems—Innovation

Normally we think of innovation in conjunction with a product. However, any area of a service, business, or operations can be innovated and improved. Over decades Toyota even used innovative thinking routines to further improve processes of cutting-chip management its machine shops.

The following examples—process technology, sensory technology, and industrial washer—were not invented by Toyota, but they adapted the concepts to cutting-chip management and made them work for their respective situation at the time:

Process technology: In the mid-1960s, Toyota eventually adopted transfer machine technology, which was common in the West for high-volume production lines. Transfer lines and flexible machining centers are also used today, depending upon the situation. But in the 1960s, instead of using hundreds of small machines in production, each with its own chip-management system (coolant flow, air blow, tanks, pumps, separation system, etc.), larger combined systems were utilized in transfer machines to great effect. This vastly reduced the number of systems to be sequenced and managed at the local level and instead placed the burden of work (and in reality waste) in a more central location where it could be better managed. It simplified the task of waste management for cutting-chip control. Unlike most competitors, however, Toyota built its own transfer machines at affiliated companies, like Toyoda Machine Works, or internal facilities like Teiho Machine Tool Plant. This practice along with thoroughly documented machine standards allowed Toyota to carry over its knowledge gained and best practices from Type 1, Type 2, and Type 3 problem solving. Type 4 innovation in equipment is often (but not always) done over longer periods.

Sensory technology: The famous jidoka concept is over 100 years old and dates back to the loom business of Toyota. However, every generation of production equipment since has involved greater use of sensory technology by Toyota process designers to enhance safety, build in quality, and prevent equipment downtime. Today sensors and lasers can check dimensional accuracy of work in process as well as cleanliness of tools and critical work surfaces. In the continuing spirit of jidoka, problems or abnormalities are highlighted before the machine can even cycle.

Industrial washers: No matter how carefully you manage cutting chips, some still adhere to the part and must be removed by an industrial washer before the part can be assembled into a precision engine. Every manufacturing company faces similar problems requiring cleaning. The answer for decades at Toyota and other companies was to utilize industrial-sized washing machines with pressure nozzles mounted inside the machine and moving conveyor lines (like a car going through an automated wash system). Every generation the washer became larger, more expensive, more difficult to maintain, and harder to keep clean. Some cutting chips still tended to remain, especially on square objects such as cylinder heads or cylinder blocks.

One day an employee questioned the whole system design. The idea of using high pressure nozzles outside the part to spray inward (pushing the chips further inside) struck him as incorrect. What if (hypothesis) the part was simply dunked in a tank via a robotic arm and swished around with an agitated motion. Wouldn't this process work better and be far simpler? Several experimental tests were conducted and the multi-dunk tank and agitate solution was found to be far superior: cleaning the problematic parts of foreign debris. Cost, ease, operation, space, energy, flexibility, and every other dimension were considered.

Summary

The *Five Whys* examples of a simple cutting-chip control problem show why it is necessary to consider a basic problem from different vantage points over time:

- Type 1 troubleshooting (daily cleaning and troubleshooting) helps immediately, and often solves the hourly or daily problem, but it usually fails to prevent problem recurrence in the long run.
- Type 2 gap-from-standard problem solving (use of strainers) emphasized root causes at a more fundamental level. It strives to solve more persistent problems and prevent them from recurring. This approach relies on deliberate and convergent styles of thinking about actual cause and effect relationships.
- Type 3 target-state problem solving (cutting-point management) presented a more creative way to solve the problem, led by divergent and open-ended thinking routines. The heart of the approach involves considering ideal-state scenarios, which prevent or eliminate the problem from occurring at a more fundamental level.
- Type 4 innovation routines (new equipment) build further upon the target-state thinking of the previous approach and are even more open-ended. This also can involve new technology and require a willingness to experiment with completely new ideas.

Learn to use the four types of problem solving properly, and review improvement potentials accordingly. There is no one way that necessarily works best all the time. Whether you troubleshoot, solve a gap-from-standard problem, create a target-state improvement, or seek innovation depends upon circumstances, priorities, resources, timing, necessities, etc. Thoroughly understanding all the types for improvement will help you foster greater improvement in the long run.

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