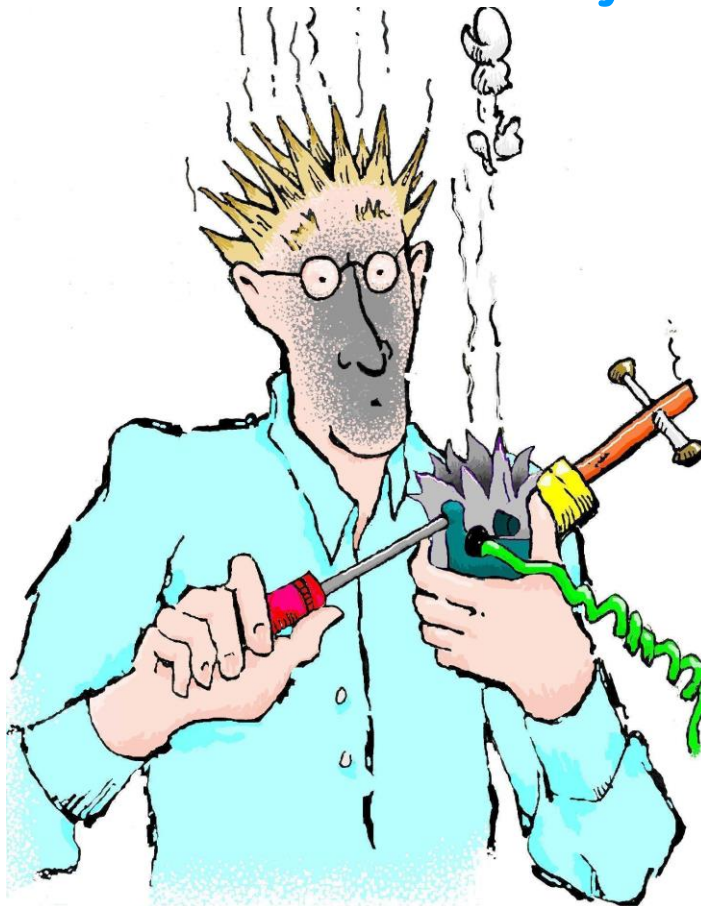
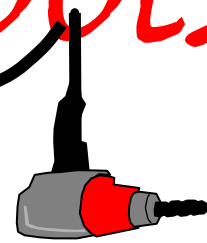


TRIZ POWER TOOLS

Job #5 Resolving Problems

May 2013 Edition



*How to Systematically
Tackle Tough Problems*

TRIZ Power Tools

Job 5—Resolving Problems

July 2013 Edition

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TRIZ Power Tools by Collaborative Coauthors

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The Algorithm

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Introduction

(If you are reading the PDF format—navigate the algorithms with the “Bookmarks” to the left. L1, L2, L3 correspond to levels of the algorithm. The levels are hierarchal; you can go as deeply as required to resolve your problem. Lower levels (L1, L2) have consolidated methods. If you are using the book then use the Table of Contents for the Algorithm)

I think I have a problem. I know I have a problem. I’m worried that there might be a serious problem but I don’t have any evidence. Problems come to us at varying levels of certainty. Sometimes they are painfully obvious while other times, we have an uneasy feeling. Regardless of the certainty, here we are and now we need to do something about it.

All problems are not created equal

This is a book for helping inventors, scientists and service innovators to solve difficult problems. It is often hard to tell the difficulty of a problem until we attempt to solve it. Common sense or intuition is sufficient to clear most hurdles. “Recreational” problem solvers are acquainted with the endorphin rush of intuitive problem solving. There is nothing wrong with free-ranging problem solving, but we may notice that our attempts to intuitively solve a “simple” problem are sometimes hampered by unforeseen difficulties.

There is a popular website which presents problems which can be solved for profit. One such problem related to a large problem in developing countries regarding the quality of air inside homes that cook and heat with unventilated stoves. Many of the fires are fueled by materials such as wood and charcoal. The problem with these materials is that they produce large amounts of particulates which compromise the respiratory system. People with damaged lungs become susceptible to many diseases that a healthy body would resist. This is especially true for young children. Many millions of children die each year from diseases related to a compromised respiratory system.

The specific problem involved the use of non-edible oils which were readily available from certain plants and could be manufactured cheaply. A stove was designed to burn these oils as efficiently as possible and it was not working as well as the manufactures would have liked. The problem was that it would clog with soot very rapidly and needed cleaning after several hours of use. The challenge was to prolong the time to cleaning or eliminating cleaning completely.

When I presented this problem to a number of colleagues, the immediate response was that this was a simple problem that could be resolved with known technology. I felt, likewise, that it would be easy to come up with a solution. We wondered how the company could be so naïve to propose such a simple problem and then offer so much for its solution.

Without the aid of any innovation tools, I “brainstormed” various concepts and created small prototypes and tested them. First, I learned how to ignite an olive oil flame by forming a wick into a special shape. I also built a small canister of oil which was heated to create a flammable gas. It slowly dawned on me that my “common knowledge” concerning flammable liquids had little to do with this problem which was much harder than I realized.

The operation of the stove required the oil to be heated until it was vaporized. Once it was vaporized, the vapor was mixed with air in the correct proportions to burn efficiently and without soot. While the flame was clean, the oil was coking in the heating chamber and in the lines that fed the burners. It turns out that such oils vaporize and coke at the same temperatures, unlike benzene, white gas or alcohol. If you are going to use the phenomena of vaporization by heating, some fraction of the oil will coke, wherever it is.

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The fact that I could not easily solve this problem was a bitter pill and I realized that we were the naïve ones. It can be deflating to admit that our “common sense” is not sufficient for such an easy problem. Our pride drives us to struggle for a time, but we eventually realize that the solution is beyond our experience and intuition. We give up, try again later or recognize that we need stronger medicine. The algorithms of this book are stronger medicine.

The Most Common Job of Inventers

Of the six jobs covered in this series of books, fixing problems is the most common. Why is this? One reason is the recursive nature of solving problems. It is rare that only one improvement is required. Solutions to one problem often generate new problems that still require resolution. Most “good” solution concepts start as “sow’s ears”. Our job is to turn them into “silk purses.” Unfortunately, most of us have been taught that this is not possible. Actually, this is a clear description of what really happens during the inventing process.

Another reason that fixing problems is so common is that hard problems will always arise during the evolution of any particular system. A careful study of patents for any particular system will uncover evolutionary patterns. These patterns show a particular evolutionary tendency for the system. This evolution is stopped by the inevitable contradictions that will arise as the systems evolve. The system continues further along its natural evolutionary path only after the contradiction is resolved.

One further reason for the high frequency of fixing problems is that processes of creation and simplification (books 3 and 4) often generate serious problems. (The solution to these problems was not covered in books 3 and 4 but was delayed until this book). Let’s say that we have simplified a system by making use of a physical phenomenon that replaces a feedback system with a passive control system. This is often done by using a “direct acting” element that both senses and provides actuation muscle. While such a change can greatly reduce the cost of complex systems, it is also a large change that can result in poor control performance. This simplification would almost guarantee that there will be serious problems to overcome.

Not Enough Problems to Solve?

Where do we look for problems and what types of problems can we solve with the tools of this book? Some people find it difficult to identify important problem to solve. If we know what to look for we can see that we are swimming in problems. All systems, by their very nature, carry burdens to the users and the environment. Only imaginary systems do not contain burdens. (In the companion book on simplifying, we spend a lot of time identifying these burdens). We often become used to these burdens and forget that we are carrying them. As we become familiar with the types of burdens that are possible, we can readily detect them all around us.

Another common problem is low performance of some primary feature. Low performance usually shows up when compared to other products that perform the same function. More importantly, it shows up when the target market is not satisfied and wants improved performance in order to get their job done.

Sometimes the market cannot count on the performance of a product. Perhaps the performance shifts over time or is highly variable. Some shift in performance is inevitable, but when it causes concern or anxiety in the market, it may need to be fixed.

Another common problem is when the product or service causes unintentional harm to other objects or the user of the system.

Production or service costs are also a problem that can be tackled with the algorithms of this book. High costs are symptoms of other unsolved problems. When these problems are solved, the costs will go down. Additional ways to reduce costs are shared in the other books which deal with simplifying systems and adding value to the product or service by determining the right product features. Cost is relative to perceived market value. We can effectively reduce costs by being able to charge more for the product or service.

Some Problems are More Important

While there are many problems, should they all carry the same importance? To a large degree, market and environmental considerations determine the relative importance of problems. If a problem is blocking or hindering the target market from getting a job done, this raises the level of importance. If the environment or mankind is hurt by a product or service, this is also an important problem to solve. The authors of this book are keenly aware of the need for scientists, engineers and other problem solvers to solve the problems that society has placed on the environment.

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L1-Look for Hidden Problems?

When we build a good machine, we also build a bad machine. The bad machine is always operating and we may not even know it. Let's say that we build a transmission for a food mixer. Everything seems to work well the first thousand times that it is operated. If we then open the machine and examine the pieces, we discover that many of the plastic gears have begun to wear. Perhaps some are close to failure. We did not purposely build a machine to wear gears. The gear wearing machine operates in the background each time the food mixing machine is operated. The bad machine is usually hidden when we first create the product or service. It will take time for the machine to expose its mischief.

It is human nature to focus on problems that result in immediate pain. These problems cry for our focus and attention. However, waiting to discover the problem is often disastrous. Here are some examples of when you might want to discover hidden problems:

- When the operation of the product could potentially cause serious injury or death.
- There are maintenance agreements with the customer. They pay you to maintain the product and unanticipated repairs decrease profit.
- A good market introduction is required.
- It is necessary to create or restore the reputation as a trouble-free product or brand.

There are many reasons that problems are hidden. We have already mentioned the issue of wear or degradation over the course of time. Another reason is that we have not anticipated that the product or process could be used in unsavory environments. Potential environments are unlimited. We may think that we understand the environment of the target market, but we must always remember those who are willing to experiment with the product in unusual and dangerous ways and in unusual places.

Perhaps the most common reason that problems are hidden is that we have learned to compensate for them and we forget that the problem exists. Let us take the extreme case where the compensation is expensive *and* time consuming. Surely no organization would forget that such a problem exists. Expensive and time consuming problems often occur when we need to calculate the effect of a problem and then overpower the effect with something else in the system.

When transportation vessels move through the air or water, there is drag which robs the system of energy. It is a constant drain. The ultimate speed of a vehicle is related to the fluid drag and the power that we need to overcome the drag. Virtually all of the fuel that is expended is due to this drag! (Think of the rivers of fuel that could be conserved if this problem were solved).

How do we compensate for this and design for drag? Typically models of drag are created which are related to such things as the velocity of the object, its shape and the properties of the fluid that it is moving through. Usually, it is necessary to substantiate the model by testing in wind tunnels or in flowing water. There is a back-and-forth comparison of the model to tests until there is confidence in the model.

Now that we have a substantiated model, we can anticipate the driving force that is required to overcome these drag forces. It can be used to consider different configurations of the vehicle and anticipate the drag for each concept.

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What we ultimately learn from the modeling and testing is how hard the drive system needs to push. When there is a need to perform these calculations often, we hire people with the skills to do this and build organizations to support them.

Notice what has happened. First, we found a way to quantify drag without the need to build the actual vehicle. Second, we found a way to compensate for the drag by overpowering it. Next, we institutionalized a process to routinely calculate and overpower the drag. Finally, we created an organization which can repeatedly accomplish this.

The problem with this is that very few people are working on the problem of entirely removing the base problem of drag. Most have accepted “the inevitable reality” so the next best thing is to compensate for it. By routinely grinding through a compensation process, most have forgotten that the fundamental problem of drag. The problem becomes “hidden”.

While this may seem like an extreme example, think about your own industry and the number of people that are employed to model, accurately calculate and compensate for known problems. The “success” of this process has convinced companies to structure the organization around these procedures. Unfortunately few are left that are sensitized to the base problem and also feel they have the capacity to tackle it.

L1-Method

Step 1: Clarify the need to look for hidden problems—is there a compelling need?

Step 2: Brainstorm various problems that might exist throughout the lifecycle of the product. Consider yourself a saboteur. How would you create problems in the system that would show up much later or would be difficult to detect?

L2-Clarify the Need to Look for Hidden Problems

If no problem is known, should we search for hidden problems? The answer to this type of question is largely a matter of history and the type of offering. Could hidden problems cause severe consequences? Is the physics of the offering well understood? Have a high percentage of the offerings had hidden problems? If the answer to any of these questions is “yes” then it may be wise to search for hidden problems. On the other hand, if you are beginning with a known problem and you bypass this step, there may be a tendency to forget the need to look for further problems following the creation of solution concepts. Remember that problem solving is recursive. It is easy to forget potentially hidden problems in the excitement of finding solutions.

L2-Method

Step 1: Is the severity of failure high?

Step 2: Has there been high tendency to have hidden problems in the past?

Step 3: Is this system new? Is the physics well understood?

Step 4: Decide whether or not to look for hidden problems.

Step 5: If the need for searching for hidden problems is low or the problem is already known, then continue to the next chapter.

L2-Map the Life-Cycle Jobs

It is easy to imagine products and services at the point of operation. This is the moment that these systems were created for. However, there are many more functions that the system performs and many more functions that are performed on the system. These functions need to be included in our consideration of potential problems of the system.

L2-Method

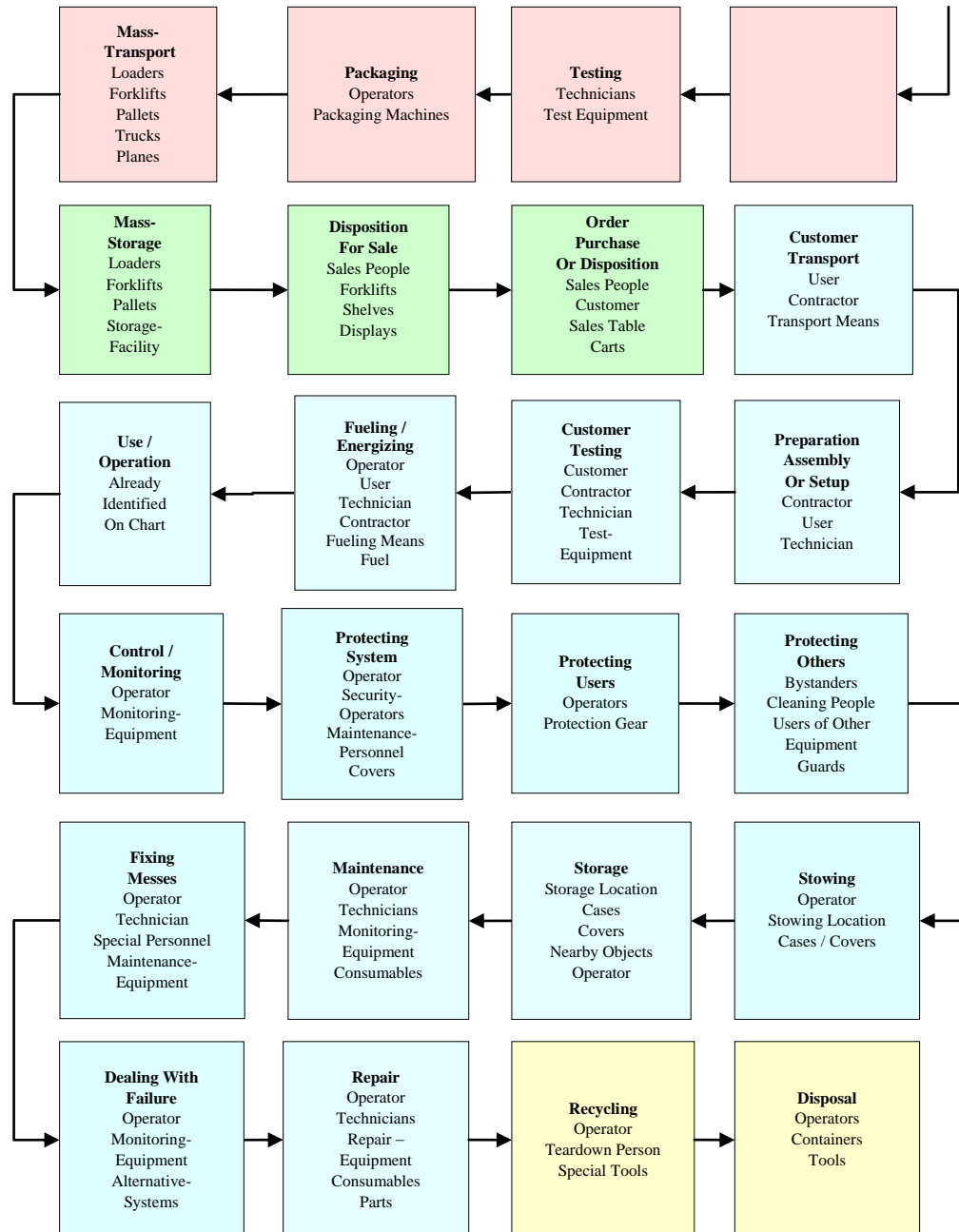
Step 1: Consider the main jobs required for and by the offering by considering each stage of the Life-Cycle Map on the following page.

Step 2: Each color in the chain represents a different market or stake holder. Identify the market or stakeholder by box color. Each market has a stake in the success of the product. As each market becomes more satisfied, the offering becomes more viable.

Step 4: If necessary, expand boxes to show the processes required to perform the actions in the boxes. Identify additional jobs that are required when looking at these functions.

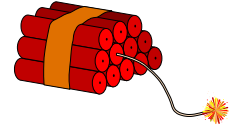
Step 5: Look for problems during each stage and expanded process of the Life-Cycle-Map

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L2-Subversion Analysis

Subversion analysis^{1 2} or Anticipatory Failure Analysis^{3 4} is a way to overcome psychological inertia to discover new ways that a system can fail. This method was first introduced in the approaches for looking for problems. Effectively we ask: If you were a **Saboteur**, how would you cause the problem?



Method

Step 1: Identify the unwanted effect..

*Step 2: Act as if you were a **Saboteur**, how would you cause the problem given the existing system? How would you keep this from being detected? Find a physical phenomenon that could be used to create or hide the desired effect. **Use the Effects Database to perform this.** (The effects database is too large to be provided in this material. More complete versions can be found in for-profit software. A simplified version can be found at function.creax.com)*

Step 3: Identify the required resources to make the effect work at all. For instance, if the effect is mechanical strain, look for objects or resources in the environment that might potentially push on the object. If the resources do not exist, then consider how they might temporarily exist or be formed through chemical reactions, etc. Consider how these harmful resources might exist naturally in small quantities from what is available. If no way can be found then consider that this effect may not be possible.

*Step 4: If the resources are available then **Boost the effect** until it is sufficient to cause the problem.*

--Identify the parameters (knobs) of all components (those acting and those being acted upon) which have an effect to make things worse. This means that either the effect of the thing that is acting is boosted or the weakness of the object which is being acted upon becomes worse.

--Change these parameters so that the effect becomes large enough to cause harm.

Step 5: Repeat all steps with each way that the system could fail.

1 Genrich Altshuller, Boris Zlotin, Alla Zusman, Vitalii Filatov. "Searching for New Ideas." Kishniev: Kartya Moldovenyaska Publishing House, 1989.

2 Boris Zlotin, Alla Zusman, "Solving All Scientific Problems" Kishniev: Kartya Moldovenyaska Publishing House, 1989.

3 Stan Kaplan, "Finding Failures before They Find Us: An Introduction to The Theory of Scenario Structuring and the Method of Anticipatory Failure Determination." Proceedings of the 9th Symposium on Quality Function Deployment, June, 1997. <http://www.qfdi.org>

4 Kaplan, S., Visnepolschi, S., Zlotin, B., Zusman, A., 'New Tools for Failure and Risk Analysis; Anticipatory Failure Determination (TM), Ideation International Inc, Detroit, 1999.

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L1-Determine The Problem Scope

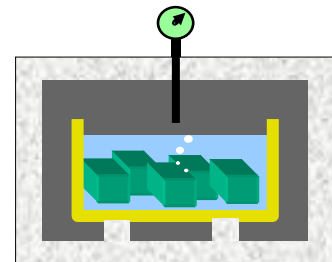
“Houston, We Have a Problem”

At this point, we have identified a problem. Either it has landed in our lap, or we went looking for it. As stated, most problems come to us as a result of just doing business or living our lives. We will consider several example problems and show how we progress through the algorithm. Note that these problems come from a variety of business and technical fields.

Just because a problem has come to our attention does not dictate that we have the right problem to solve or that we even need to solve it. In this section, we will explore the nature of the problem itself to see whether it is worthy to solve and whether we even have the right problem. For purposes of illustration, we will consider several problems.

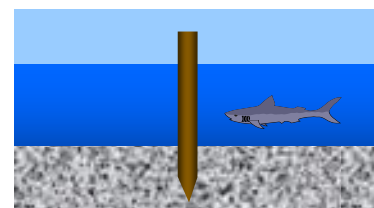
Problem—Acid Container

Metallic Test cubes are immersed in hot acid for long periods of time to test the corrosive resistance of the metals. The cubes are placed in a corrosion resistant container which is then placed in an oven. The action of the acid is sufficient to corrode the cubes, but there is a problem. The container that contains the cubes and acid is eventually corroded and has to be replaced. Replacing the container is very expensive since it is made from a very expensive material.



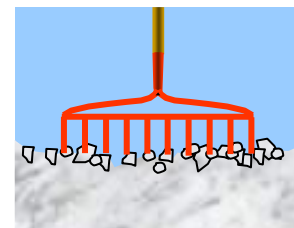
Problem—Pile Driving Speed

The driving speed of piles is very slow. Often expensive equipment such as cranes or barges is rented to perform the work. Personnel must be on hand should anything go wrong. All of this adds up to great expense while driving the piles. None of this is necessary for the primary function of the piles. How can the driving speed be improved?



Problem—Garden Rake

Let us consider the situation of a common garden rake. When the rake is used to collect loose debris such as rocks and loose weeds over an uneven surface, a problem arises: The rake “leaks” some of the debris that is to be collected under the tines and several strokes are required to fully collect the debris.



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Once we have a starting problem, we need to determine the scope of the problem that we are actually going to solve. This implies that the problem that is presented is not necessarily the problem that we will solve. We start with a problem and evolve it by a series of questions. Gradually, the problem is changed into the one that we will begin with. Even then, as we perform the causal analysis, we may focus our thinking onto different areas. We will even consider solving alternative problems. At this stage, though, it is sufficient to begin with a problem where the product or service does not comply with stated requirements, has sufficient penalty and has a sufficiently high expectation to excite all involved. Remember, the greater the experience, the greater the confidence, the higher the expectations.

L1-Method

Step 1: What is the beginning problem. We may move away from this, but state the problem as originally presented.

Step 3: What are the product or service requirements that are not being complied with?

Step 4: What is the operating environment?

Step 5: What is the deviation from requirements?

Step 6: What are the penalties of not meeting the requirements? Is it really worth pursuing?

Step 7: What are the constraints (time, resources, etc.) on the solution?

Step 8: What is the expectation for the solution? How high is the bar to be set in all of the above areas? (The greater the experience, the greater the confidence, the higher the bar can be set).

L2—Who is Affected?

If we have performed the previous jobs that innovators do (identifying markets, picking features that will excite the market, creating good upper-level requirements for the product) we will have a good idea of who the customer is. These jobs are covered in detail in two other books from this series. It is not necessary to go into such detail in order to solve problems. However, it is helpful to clarify the job and special circumstances of the customer.

L2-Method

Step 1: Who is affected? What is the primary job that they are trying to do?

Step 2: What are the special circumstances under which this job is done?

Step 3: What is a typical profile for this customer?

Example—Acid Container

Step 1: Who is affected? What is the primary job that they are trying to do?

The lab is affected. The primary job is to determine the capability of various metallic materials to resist corrosive environments.

Step 2: What are the special circumstances under which this job is done?

The special circumstances are under a laboratory setting that may be operating for periods of time without laboratory personnel present.

Step 3: What is a typical profile for this customer?

The typical profile is someone responsible for buying and maintaining laboratory equipment. These people usually respond to the needs of scientists or engineers that require this type of testing capability. They may also be responding to the requests of lab technicians.

Example—Pile Driving Speed

Step 1: Who is affected? What is the primary job that they are trying to do?

The construction company is affected. The primary job is to create a supporting structure for building that must stand above the water and waves.

Step 2: What are the special circumstances under which this job is done?

The special circumstances are that the piles must be driven into the sea bed covered by water.

Step 3: What is a typical profile for this customer?

The typical customer is a construction company which specializes in driving piles.

Example—Garden Rake

Step 1: Who is affected? What is the primary job that they are trying to do?

Home gardeners are affected. The primary job is to gather debris in a garden.

Step 2: What are the special circumstances under which this job is done?

The special circumstances are to gather the debris over any type of ground or terrain.

Step 3: What is a typical profile for this customer?

The typical profile is a home gardener.

L2—Clarify the Requirements Related to the Problem

The previous step of problem awareness would be perfectly in order if our knowledge of the product or service requirements was perfect. The awareness of a problem assumes that we understand the requirements related to the problem and can detect a deviation or potential deviation from them. This is a common, yet dangerous, assumption and can lead to further problems in the problem solving process. It is possible that there is no need to solve the problem. For instance, the product or service is operating as required in an unusual environment that it was not designed for. (This customer may represent an untapped market that has unusual expectations. Refer to the book on identifying new markets). It is also possible that the problem is greatly understated and more urgent than originally thought. If for no other reason, the problem solver should know what the target requirements are so that the required improvement is clear.

In this step we clarify how the market needs have been translated into product or service features and specific requirements related to the problem. Usually these have already been determined, but it is necessary to clarify these requirements here.

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It is entirely possible that the problem may be solved during this step of the algorithm. Knowing the requirements may make the problem unnecessary to solve or the solution may be obvious.

L2-Method

Define specific requirements of the system related to the identified problem.

Example—Acid Container

Define specific requirements of the system related to the identified problem. In this case, the acid corrosion system must handle all acids. It must contain 20 cubes measuring 1x1x1 inches. The whole system was sold on the basis of costing the researchers less than \$500 per year to maintain.

Example—Pile Driving Speed

Define specific requirements of the system related to the identified problem.

There is no specified driving time. Less is always better.

Example—Garden Rake

Define specific requirements of the system related to the identified problem.

The less re-stroking, the better.

L2—Clarify the Operating Environment

The offering must deliver certain performance characteristics while working in a specified environment. Usually these have already been determined, but it is necessary to clarify these requirements here.

L2-Method

Clarify the environment in which the system exists during setup, powering, operation, maintenance, cleanup, stowing, storage.

Example—Acid Container

Clarify the environment in which the system exists during setup, powering, operation, maintenance, cleanup, stowing, storage.

The cubes must be corroded in ovens held between room temperature and 340 degrees Fahrenheit.

Example—Pile Driving Speed

Clarify the environment in which the system exists during setup, powering, operation, maintenance, cleanup, stowing, storage.

The piles are driven offshore in no less than 4 ft of water. The piles must be driven in inclement weather with waves up to 4 ft in height. There is no guarantee as to seabed hardness or the types of rocks, that will be encountered.

Example—Garden Rake

Clarify the environment in which the system exists during setup, powering, operation, maintenance, cleanup, stowing, storage.

The environment is the typical backyard. This type of rake in question is typically sold in home improvement stores.

L2—Clarify the Base Problem

Having concluded that there is a problem or risk, we would like to capture this problem in a very short phrase that describes what we want to improve. We will use this for both the simplified causal analysis and the causal analysis charts.

Let's consider a situation where we are measuring the effect of acids on various metals. In order to investigate the corrosive effects of acid, we form cubes of the metal and place them in a container filled with acid and then heat them in an oven. After a period of time, the cubes are removed and studied. Unfortunately, the container that contains the acid becomes corroded and must be removed periodically. This operation is very expensive and we would like to reduce the cost of replacing the container. I could state the problem in long form: "The cost of replacing the container is high." The improvement could be shortened to a single phrase: "Cost of replacement is high".

The improvement is the dependant variable in an important equation that we are about to write. In the six-sigma world, this is often referred to as the big Y. In summary, the big Y is the main disadvantage that we would like to improve.

In this step, we will put into practice what we have just talked about. We will isolate the main problem that we are dealing with by asking: What is the base problem? In truth, the base problem causes further problems or penalties, so we need to make a decision on how far we are going to drill down. This is a decision for the problem solver. We would like to have the problem at a level that most of the causes will be under our control.

L2-Method

Step 1: Identify the main parameter that must be improved based upon the requirements.
Y =

Step 2: Determine whether we want to consider the effects of this problem as the Base Problem. We would like the problem to be at a level that most of the causes are under our control.

Step 3: Verify that the customer really cares that the problem is solved at this level.

Step 4: Write the base problem as a short statement. Usually this is stated as a knob and a setting.

Example—Corrosion of Acid Container

Cubes are placed in warm acid to investigate the effect of various acids on the cubes. Unfortunately, the container that holds the acid and cubes is corroded. The container is made from gold and is very expensive to replace. Because the acid is so reactive and the test is performed often, the pan must be replaced frequently.

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Step 1: Identify the main parameter that must be improved based upon the requirements.
Y = Cost of Replacement

Step 2: Determine whether we want to consider the effects of this problem as the Base Problem. We would like the problem to be at a level that most of the causes are under our control.

This will be the Base Problem.

Step 3: Verify that the customer really cares that the problem is solved at this level.

The customer cares sufficiently about the resolution of the problem at this level.

Step 4: Write the base problem as a short statement. Usually this is stated as a knob and a setting. The cost of replacement is high.

Example—Pile Driving Speed

The driving speed of piles is very slow. Often expensive equipment such as cranes or barges are rented to perform the work. Personnel must be on hand should anything go wrong. All of this adds up to great expense while driving the piles. None of this is necessary for the primary function of the piles.

Step 1: Identify the main parameter that must be improved based upon the requirements.
Y = Driving Speed

Step 2: Determine whether we want to consider the effects of this problem as the Base Problem. We would like the problem to be at a level that most of the causes are under our control.

This will be the Base Problem.

Step 3: Verify that the customer really cares that the problem is solved at this level.

The customer cares sufficiently about the resolution of the problem at this level.

Step 4: Write the base problem as a short statement. Usually this is stated as a knob and a setting. The driving speed of the piles is low.

Example—Garden Rake

Let us consider the situation of a common garden rake. When the rake is used to collect loose debris such as rocks and loose weeds over an uneven surface, a problem arises: The rake “leaks” some of the debris that is to be collected under the tines and several strokes are required to fully collect the debris.

Step 1: Identify the main parameter that must be improved based upon the requirements.
Y = Leakage of Debris

Step 2: Determine whether we want to consider the effects of this problem as the Base Problem. We would like the problem to be at a level that most of the causes are under our control.

This will be the Base Problem.

Step 3: Verify that the customer really cares that the problem is solved at this level.

The customer cares sufficiently about the resolution of the problem at this level.

Step 4: Write the base problem as a short statement. Usually this is stated as a knob and a setting. The leakage of debris is high.

L2—Clarify the Importance of Solving the Problem

Because a problem is evident, it does not follow that it requires solving. We need to have an idea of how big this problem is to the market, business, mankind or nature. This is actually a very important step that is often missed by the problem solver. An effort is about to be started which may last for several months or years. A solution may be found, only to realize that nobody cares about the solution and there is little interest in implementing it.

As stated previously, the base problem is one of the causes of this penalty. If we can solve the problem, the penalty should go away. We may conclude that this penalty *is* the base problem.

Another issue has to do with how well the solution of the problem aligns with the goals and strategy of the organization.⁵ Sometimes, solving the problem does not go far enough for the organization and the bar needs to be raised. Or, the solution of the problem may have little to do with the direction that the business wants to move. You may be solving a problem for a product line that no longer fits the charter and strategic direction of the company.

L2-Method

Step 1: Gather costs and penalties associated with these disadvantages.

Step 2: Is there a tangible demand for this system or will the improvement give a limited improvement to the customer? Will it impact the business sufficiently?

Step 3: Is there really an interested customer?

Step 4: Is this problem worth pursuing? What is the dollar value to the company?

Step 5: Is solving this problem aligned with the strategy of the business?

Example—Corrosion of Acid Container

Step 1: Gather costs and penalties associated with these disadvantages.

Yearly cost is \$5000.

Step 2: Is there a tangible demand for this system or will the improvement give a limited improvement to the customer? Will it impact the business sufficiently?

Yes, there is a tangible demand.

Step 3: Is there really an interested customer?

Yes, there is an interested customer.

Step 4: Is this problem worth pursuing? What is the dollar value to the company?

Yes, the problem is worth pursuing. The cost is \$5000 per year.

Step 5: Is solving this problem aligned with the strategy of the business?

⁵ Dwayne Spradlin—Are you Solving the Right Problem? Harvard Business Review –September 2012 Page 85

Yes, this is a testing lab that is looking for more business.

Example—Pile Driving Speed

Step 1: Gather costs and penalties associated with these disadvantages.

The cost of renting the equipment, fuel and wages is \$1000 per pile

Step 2: Is there a tangible demand for this system or will the improvement give a limited improvement to the customer? Will it impact the business sufficiently?

Yes, there is a tangible demand.

Step 3: Is there really an interested customer?

Yes, there is an interested customer.

Step 4: Is this problem worth pursuing? What is the dollar value to the company?

Yes,. The cost is \$500 per hour which is 40% of the cost of installing the piles.

Step 5: Is solving this problem aligned with the strategy of the business?

Yes, the business of the company is driving piles.

Example—Garden Rake

Step 1: Gather costs and penalties associated with these disadvantages. The primary cost is in the time associated with doing a typical raking job and what % of the time is associated with re-raking an area. Currently, the re-raking time approaches 200% of the time normally associated with raking.

Step 2: Is there a tangible demand for this system or will the improvement give a limited improvement to the customer? Will it impact the business sufficiently?

Few people even realize that this problem exists.

Step 3: Is there really an interested customer?

This is debatable.

Step 4: Is this problem worth pursuing? What is the dollar value to the company?

This is probably not worth pursuing except as an example problem for this book.

Step 5: Is solving this problem aligned with the strategy of the business?

Assuming that we are dealing with a company that intends to continue manufacturing rakes as one of its main products, the answer is “yes”.

L2—Clarify the Constraints on Solving the Problem

The first requirement that we need to address are the business constraints on solving the problem. The clarification that we receive at this step will determine all else that we do! This is where we need to invoke some less-than-common sense and decide what we will limit ourselves to. Is this the type of problem that is of sufficient importance that we need to perform a full causal analysis? Or, will a simple one suffice. Should we seek to

overhaul the system? Or should we simply fix what is already there with as little change as possible? Do we need twenty or thirty well evolved alternatives or is one good one sufficient? This is the step where we resolve these issues.

L2-Method

Step 1: How much time do we have to solve the problem?

Step 2: What are our budget constraints?

Step 3: How many solutions alternatives are required?

Step 4: Will a simple causal analysis be sufficient?

Step 5: How much change to the system will we allow?

Example—Acid Container

Step 1: How much time do we have to solve the problem? This is a yearlong research project.

Step 2: What are our budget constraints? \$50K

Step 3: How many solutions alternatives are required? We want several good alternatives on this problem.

Step 4: Will a simple causal analysis be sufficient? In this case, we will assume that a full causal analysis is warranted.

Step 5: How much change to the system will we allow? In this case, we can allow a large amount of change to the system. A full overhaul may be sufficient so long as it simplifies everything. This is a long-standing problem that can be worked in the background and the impact is high on this small business.

Example—Pile Driving Speed

Step 1: How much time do we have to solve the problem? 2 weeks.

Step 2: What are our budget constraints? \$5K

Step 3: How many solutions alternatives are required? A few good alternatives are sufficient.

Step 4: Will a simple causal analysis be sufficient? A simple causal analysis will be sufficient.

Step 5: How much change to the system will we allow? We will likely allow a medium change to the system. The costs of pile driving are significant, but the problem solvers are given little time to resolve the problem.

Example—Garden Rake

Step 1: How much time do we have to solve the problem? This is a yearlong research project.

Step 2: What are our budget constraints? \$50K

Step 3: How many solutions alternatives are required? We want several good alternatives on this problem.

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Step 4: Will a simple causal analysis be sufficient? In this case, we will assume that a full causal analysis is warranted. The company really needs a full overhaul of their rake product and it is long past due.

Step 5: How much change to the system will we allow? In this case, we can allow a large amount of change to the system. A full overhaul may be sufficient so long as it simplifies everything. This is a long-standing problem that can be worked in the background and the impact is high on this small business.

L2—Solution Goal

Finally, we want to set the expectation for ourselves of what we think a good solution is. It is important to set high expectations in order to receive an enthusiastic response from those who will fund you and other team members. We are going to say “Ideally we want...” but there are no absolute ideals here. For every ideal you can describe a higher ideal until there is no system and no need for the function that it serves. On the other hand, we can promise more than we are capable of. With experience comes confidence in using these methods. With confidence comes a willingness to increase expectations. At a minimum, we should at least meet the requirements related to the problem. We have already determined the minimum solution (the requirements) in a previous step. In this step we will ask: What level of solution would allow the system to progress several generations without again becoming the weak link in the system?

Finally, we need to clarify how we will measure the improvement. If we cannot measure the effectiveness of the solution then we effectively have no solution.

L2-Method

Step 1: If the system is not viable (commercially or otherwise), what level of solution is required to make it viable?

Step 2: What level of solution would allow the system to progress several generations without again becoming the weak link in the system?

Step 3: How will the benefits be measured?

Example—Acid Container

Step 1: If the system is not viable (commercially or otherwise), what level of solution is required to make it viable?

The current solution is viable, but problematic.

Step 2: What level of solution would allow the system to progress several generations without again becoming the weak link in the system?

What we ideally would like to happen is: the acid corrosion system must handle all acids. It must contain 20 cubes measuring 1x1x1 inches. The whole system should cost nothing to maintain. (This is a step up from the minimum requirements).

Step 3: How will the benefits be measured?

The benefits are measured in yearly costs to replace the container.

Example—Pile Driving Speed

Step 1: If the system is not viable (commercially or otherwise), what level of solution is required to make it viable?

The current solution is viable, but problematic.

Step 2: What level of solution would allow the system to progress several generations without again becoming the weak link in the system?

What we ideally would like to happen is: the cost of driving piles about \$500/ hour. A typical pile takes 8 hours to drive in. The total cost related to waiting is \$4000 per pile. We would like to reduce this to at least a quarter of the cost by driving the piles in less than 2 hours apiece.

Step 3: How will the benefits be measured?

The benefits will be measured in dollars per pile.

Example—Garden Rake

Step 1: If the system is not viable (commercially or otherwise), what level of solution is required to make it viable?

The current solution is viable, but problematic.

Step 2: What level of solution would allow the system to progress several generations without again becoming the weak link in the system?

What we ideally would like to happen is: no more than one rake stroke should be required to collect all of the debris in the path of the rake.

Step 6: How will the benefits be measured?

The benefits will be measured in the time to rake a standard area of various debris.

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L1-Solve with “Bright Spots”

Existing solutions or “bright spots” are described by the Heath brothers in their book “Switch”⁶. A bright spot is a pre-existing solution to a complex problem. It skips almost all of the solution process that we will describe in this book. Sometimes, it can solve extremely difficult problems. The key is to recognize that people are experimenting and solving problems all of the time. They may not be solving the exact problem that you are working on, but the solution may be close enough to use.

The example is given of an attempt to improve nutrition in rural villages in Vietnam.⁷ Malnutrition has been widespread in rural areas. The problem solvers were from a non-profit organization in the United States which had the aim of increasing the nutrition of these villagers. One could look at this as a very complicated problem. One could point to many complex problems such as the food distribution system, the farming system, widespread poverty. This was truly a problem of world hunger. On top of this, the organization was viewed with suspicion and allowed only a short period of time in the country.

Rather than perform the analysis of this book, the problem solvers took a short-cut. They looked for a pre-existing solution. First, they organized a large group of women that would be paid to look for healthy children in impoverished areas. These people had to be living under the worst possible conditions and still be healthy. They must have no other source of income. The search was successful in finding several families with healthy children. What was discovered was that the mothers with healthy children were not feeding their children with two meals a day on the traditional rice diet, but with three meals, using the same amount of rice. They were also supplementing the rice with crabs from the rice paddies and greens that would normally be passed up but were available in sufficient quantities locally.

Once the solution was found, an effort was put in place to bring local mothers to training classes put on by these successful mothers. The bright-spot spread from village to village.

L1-Method

Search for instances where the problem is already solved. The search may be very intense and take a lot of resources for a short period. Other company teams may be working on this problem already or may have solutions. What have they done?

Example—Acid Container

Search for instances where the problem is already solved. The search may be very intense and take a lot of resources for a short period. Other company teams may be working on this problem already or may have solutions. What have they done?

This is a highly specialized problem specific to this laboratory. No existing solution is found.

⁶ Switch by Dan and Chip Heath pages 27-48, Broadway Books, New York

⁷ The original reference in the Heath Brothers book comes from the book The Power of Positive Deviance by Richard Pascale, Jerry Sternin and Monique Sternin, published by Harvard Business Press pages 19-52.

Example—Pile Driving Speed

Search for instances where the problem is already solved. The search may be very intense and take a lot of resources for a short period. Other company teams may be working on this problem already or may have solutions. What have they done?

A type of pile driver is found which oscillates the pile at a resonant frequency of the ground or the pile. For the purposes of this text, we will call it a harmonic pile driver. This loosens the soil sufficiently at the tip and around the pile so that the pile goes in much more rapidly. We would like to drive the pile even faster, but this is a good start on solving the problem.

Example—Garden Rake

Search for instances where the problem is already solved. The search may be very intense and take a lot of resources for a short period. Other company teams may be working on this problem already or may have solutions. What have they done?

No solution is found.

L1-Causal Analysis

For most problems, there is an incomplete picture of what is causing the problem. Often, we know several causes and that is enough. The risk of not really solving the problem or solving only part of the problem is increased when we have an incomplete understanding of the problem.

There are two possible paths in causal analysis. The first path is to remove problematic elements without necessarily understand the cause of the problem. The second path is to deeply understand the cause of the problem which means that we understand the physics, all contributing interactions, what controls the interactions and why it is hard to change these controls. (The things that make it hard to change the controls are the contradictions).

For most people, it seems obvious that we should understand the causes of problems before we try to solve them. However, this is strangely not always necessary. Sometimes we can remove elements from a system without the need to deeply understand all causes. The famous training example is given of a Soviet lunar explorer that was experiencing difficulties in making a scheduled launch due to the vibration failure of a light bulb. This was a particularly important light bulb since it would illuminate the lunar surface in order to take pictures. The problem was that the bulb could potentially break during the launch due to the high vibrations. Many solutions had been attempted to strengthen the bulb, but it continued to break during testing. The problem was resolved by noting that it was actually not required on the moon because of the high vacuum there. The purpose of the bulb was to keep out an oxidizing atmosphere making it unnecessary on the moon.

Note from this example that had the Soviet team begun the problem solving by asking why the problematic element was required. What made it necessary in the system? In this case, the bulb does not solve a deeper problem, but it does provide an unnecessary auxiliary function. Also note that once it was noted that the bulb was not required, there was no need to do a deep analysis of the physics of failure. It was simply removed.

This is a simple example but other situations are not so simple. Many system objects are required in order to undo the harm caused by other elements. Sometimes they are required to perform supporting functions. In each case, the original system builders decided to provide the problematic system element for a purpose. It is our job to look deeply and understand the deeper reason that the object is required in the system.

L1-Method

Perform a level one causal analysis as described in the book TRIZ Power Tools—Skill #6 Determining Cause.

Example—Acid Bath

Perform a level one causal analysis as described in the book TRIZ Power Tools—Skill #6 Determining Cause.

A level one causal analysis was performed. The following diagram shows the results. Note that mostly design features are shown. Functions and results and results are not included. For instance, the contradiction—Frequency of replacement is high and low is not included. When working with level one causal analysis, it is usually sufficient to just work with design parameters.

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| | | | | |
|-----------------------------------|------------------------|-------------------------|---|----------------------------|
| Cost of Replacement is High = f { | Acid Strength is High | Acid Strength is Low | = | Corrosion of Cubes is Low |
| | Material is Gold | Material is Glass | = | Corrosion of Glass is High |
| | Corrosion Time is Long | Corrosion Time is Short | = | Corrosion of Cubes is Low |

Example—Pile Driving

Perform a level one causal analysis as described in the book *TRIZ Power Tools—Skill #6 Determining Cause*.

A level one causal analysis was performed. The following diagram shows the results.

| | | | | |
|--------------------------------|------------------------------|---------------------------|---|---|
| Speed of Driving is Slow = f { | Pile Diameter is Large | Pile Diameter is Small | = | Breakage is High (Or Driving Depth is Deep) |
| | Driver Mass is Low | Driver Mass is High | = | Breakage is High |
| | Ground Hardness is Hard | Ground Hardness is Soft | = | Driving Depth is Deep |
| | Pile Flexibility is Flexible | Pile Flexibility is Stiff | = | Pile Cost is High |

Example—Garden Rake

Perform a level one causal analysis as described in the book *TRIZ Power Tools—Skill #6 Determining Cause*.

A level one causal analysis was performed. The following diagram shows the results.

| | | | | |
|------------------------------|-----------------------------|----------------------------|---|---|
| Debris Leakage is High = f { | Tine Spacing is Large | Tine Spacing is Low | = | Collection of Small Debris is Excessive |
| | Tine Flexibility is Low | Tine Flexibility is High | = | Removal of Imbedded Debris is Poor |
| | Ground Irregularity is High | Ground Irregularity is Low | = | May Not Come that Way |
| | Amount of Debris is High | Amount of Debris is Low | = | May not Come that Way |

L2-Create a Function Diagram of the System

The first step of causal analysis is to understand what each part in the system does and then to target elements for elimination.

Several times, the author has been involved with performing a causal analysis without first understanding what the different elements in the system do. Ultimately, it was necessary to come back to this step to understand the system resources and the interaction between system parts. Function modeling⁸ is a practical and useful approach to begin to understand why objects are required in the system. A functional diagram gives a snapshot of all the elements and what they do without reference to time or sequence of operation.

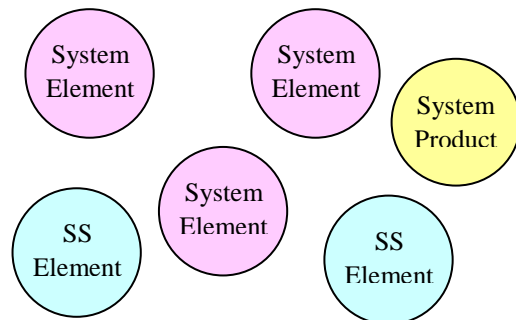
Functional Nomenclature

The following steps require a knowledge of working with functions. If you are not familiar with these approaches then go to the book TRIZ Power Tools—Skill #2 Working with Functions.

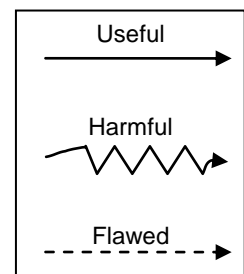
L2-Method

Step 1: Break the system down into functional elements. At this point, do not include super-system elements. (This will be discussed in the next step).

Step 2: Add Super-System elements and identify the system product. The system product is the element that the system modifies. Super-system elements are a part of the job and reside in the environment. The system product is a special type of super-system element that the system serves. The system modifies the system product.



Step 3: Introduce Modification Links including useful, flawed and harmful links. Verify that all rules for forming functions have been followed (look in the appendix for this). It is possible to discover system problems during this process because we consider the possibility of interactions between



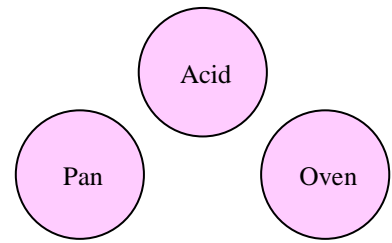
⁸ Function Modeling was first Introduced by Lawrence Miles, Jerry Leftow, and Harry Erlicher, all of General Electric during World War II in an attempt to make better use of scarce resources. Function modeling is a technique used within the broader context of Value Engineering. The idea of function analysis was to identify the functions that objects perform and then identify alternative means of delivering the same function. For deeper research into this topic, visit online: The Lawrence D. Miles Value Engineering Reference Center Collection University of Wisconsin in Madison, which contains original manuscripts and works of Lawrence Miles.

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every element. Harmful and useful but flawed modification links should be included.

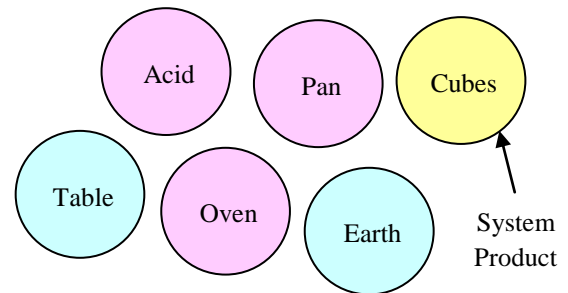
Example—Acid Bath

Step 1: Break the system down into functional elements. At this point, do not include super-system elements. The functional elements of the cube corrosion system include the acid, oven and pan.



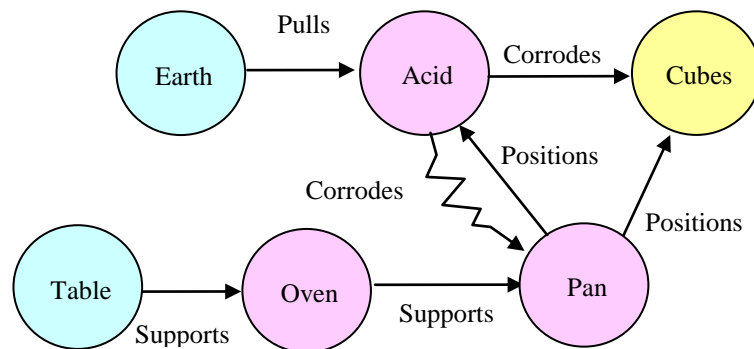
Step 2: Add Super-System elements and identify the system product.

The Super-System elements in this case are the table, earth and cubes. The cube is the system product. The cubes are what the system modifies by corroding them.



Step 3: Introduce Modification Links including useful, flawed and harmful links.

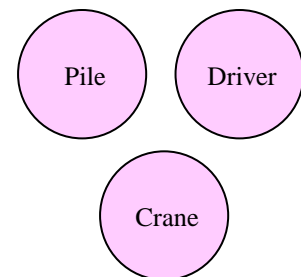
Note that this time we have included the harmful function of pan corrosion.



Example – Pile Driving

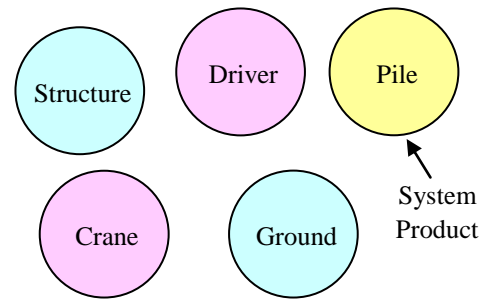
Step 1: Break the system into functional elements.

The functional elements include the pile, pile driver, and crane.



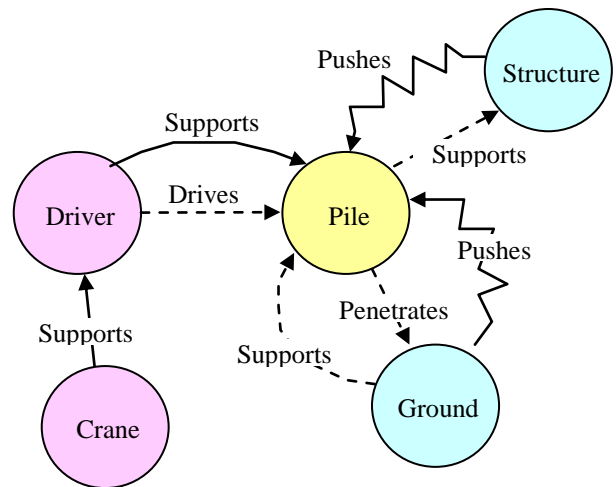
Step 2: Add Super-System elements and identify the system product.

The pile is the system product. The ground and the structure that is being supported on the pile are added as part of the super system.



Step 3: Introduce Modification Links. Include useful, flawed and harmful links.

For the pile driver that we are considering, the driver grabs the pile from the top and is able to position it at the same time that it is driving it. As the pile driver drives the pile into the ground, the ground pushes back, making the driving slow. Once the pile is driven into the ground some distance, the ground also supports the pile. Later, the ground supports the pile which supports a structure on top of it. Under an earthquake load, the structure can further push the pile into the ground and the support that the ground provides for the pile is then inadequate.

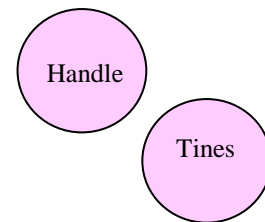


Example—Rake Leakage

“Leakage” of debris through a garden rake makes it necessary for the user to re-stroke, thus increasing the time and effort for the task of raking.

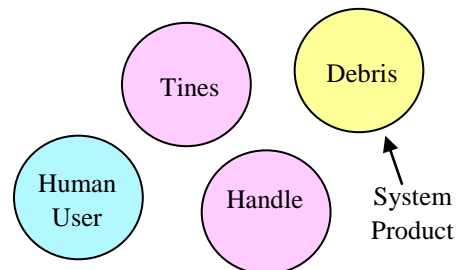
Step 1: Break the system down into functional elements.

The rake is a simple system composed of a handle and tines.



Step 2: Add super-system elements and identify the system product.

The debris that we are trying to rake up is the system product. The human user which performs the raking will be considered part of the super-system. The human user might be considered part of the system as well, if we can eliminate the person from the system.

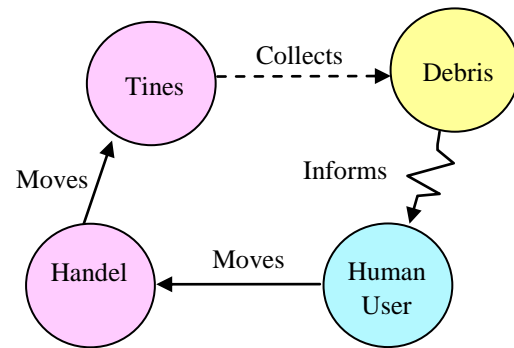


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Step 3: Introduce Modification Links. Include useful, flawed and harmful links.

The modification links are quite simple. There are no harmful functions shown, (unless someone would like to include blisters). The primary problem is that the tines inefficiently collect debris.

Note that the reason that the human user is removing the debris is because it looks bad. This is an informing function. The human detects that the debris is there and feels compelled to remove it. Note that the small debris is fine to leave. It looks ok. The large debris is what needs to be removed and currently, the tines do a poor job of removing the debris.



L2-Target Problematic Elements for Elimination

It is often surprising to see that most system objects are used to *provide support* to the main objects that do the actual work. Those parts that perform the actual work are more essential. Once we understand the function of each system element, we want to target elements in the system for elimination in order to solve the problem. While it is not always possible to eliminate these elements, it is important that we do everything possible to this end. When we eliminate any element, we reduce the burdens of the system imposed on the users and the environment.

In order to target elements for elimination, we need to understand that some elements are less important to the system and therefore impose greater burdens. Those elements that directly support the primary purpose of the system are more important and more care must be taken to eliminate or replace these elements. Replacing these elements means that we will likely be identifying a new physical phenomenon to deliver the primary function. This is usually performed only when the system has exhausted all resources and improvement has reached a point of diminishing returns. When the physical phenomenon is changed, there are many unknowns which are introduced. While this may be necessary in the long run, it can often delay the solution to the problem while these problems are uncovered and resolved.

Elements which are not directly involved in the primary function are referred to as auxiliary functions. Auxiliary functions support the primary useful function. They may only be required because something else in the system is not doing its job. It is also possible that something that already exists in the system could take over this useful function. Additionally, auxiliary functions can also be very expensive or burdensome in other ways. Good examples of this are system feedback elements which are often expensive and never directly impact the useful function.

The importance of eliminating burdensome auxiliary elements cannot be overstated. We must look for every opportunity to do this in order to solve the problem. Missing problem elements are no longer problems. All burdens

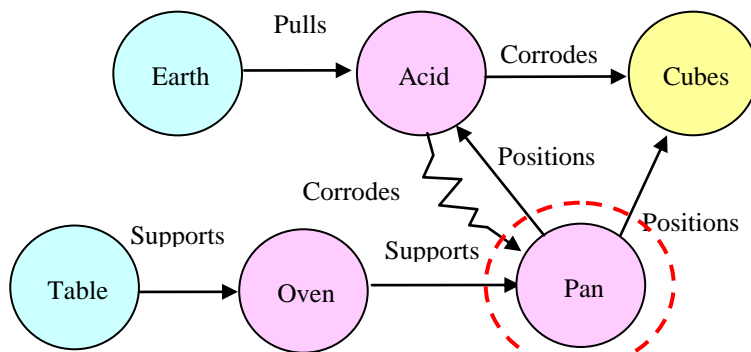
of the elements are removed and the system becomes more ideal. In this step, we will target problematic auxiliary elements for elimination and then we will look for every opportunity to eliminate them.

L2-Method

Identify the primary useful function and the auxiliary elements in the system and then target auxiliary elements which are involved in the problem for elimination.

Example—Acid Container

Identify the primary useful function and the auxiliary elements in the system and then target auxiliary elements which are involved in the problem for elimination.

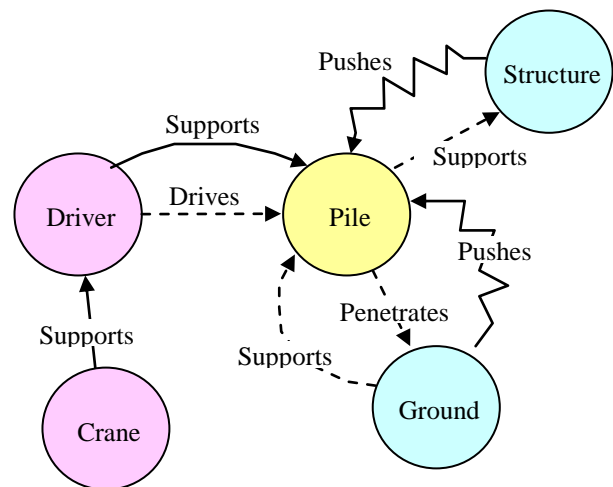


The primary useful function is to corrode the cubes. The acid is directly involved. All other elements are auxiliary objects which support this function and can therefore be eliminated. In particular, the pan should be targeted for elimination since it is involved in the problem at hand.

Example –Pile Driver

Identify the primary useful function and the auxiliary elements in the system and then target auxiliary elements which are involved in the problem for elimination.

The driver and the ground are related to the problem. The ground is required to perform the function of supporting the pile. The driver performs a useful function on the system product. If we remove the driver, we must find something else in the environment to drive the pile or the pile must drive itself. The crane could be target for elimination, but the removal of the crane is not related to resolving the problem of slow driving speed. The



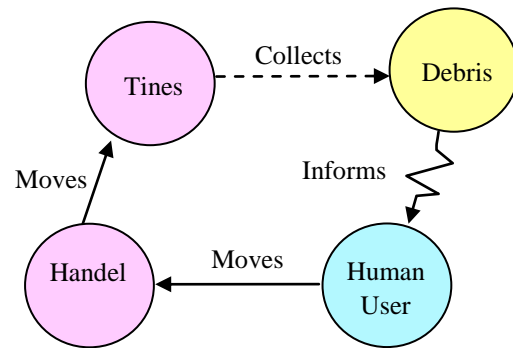
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decision is made to not target any element for elimination. We will use causal analysis to determine how to improve the situation.

Example—Debris “Leakage”

Identify the primary useful function and the auxiliary elements in the system and then target auxiliary elements which are involved in the problem for elimination.

If we were a home owner, we would be concentrated on removing the rake. In this case, it is possible to do this if we can solve the problem of the debris informing the human user. There might be very satisfactory solutions for a home owner. Note that, the debris is not required in the system. Since this is an informing function, we could have idealized this by eliminating the debris.



We are going to move forward with the idea that we represent a company that is trying to manufacture products that remove debris and perform other functions that rakes perform. The decision is made to not target any elements for elimination. Instead, we will use causal analysis to identify features that control the leakage of debris through the tines.

L2-Determine Why Targeted Elements are Required

Once we have determined which elements are problematic or cause burdens, we would like to determine the reasons they are required so that we can remove the reason if possible. This is one of the most direct methods for solving problems. The book TRIZ Power Tools—Skill #7—Determining why Targeted Elements are Required provides the approaches.

L2-Method

Go to TRIZ Power Tools—Skill #7—Determining Why Targeted Elements are Required and follow the approaches.

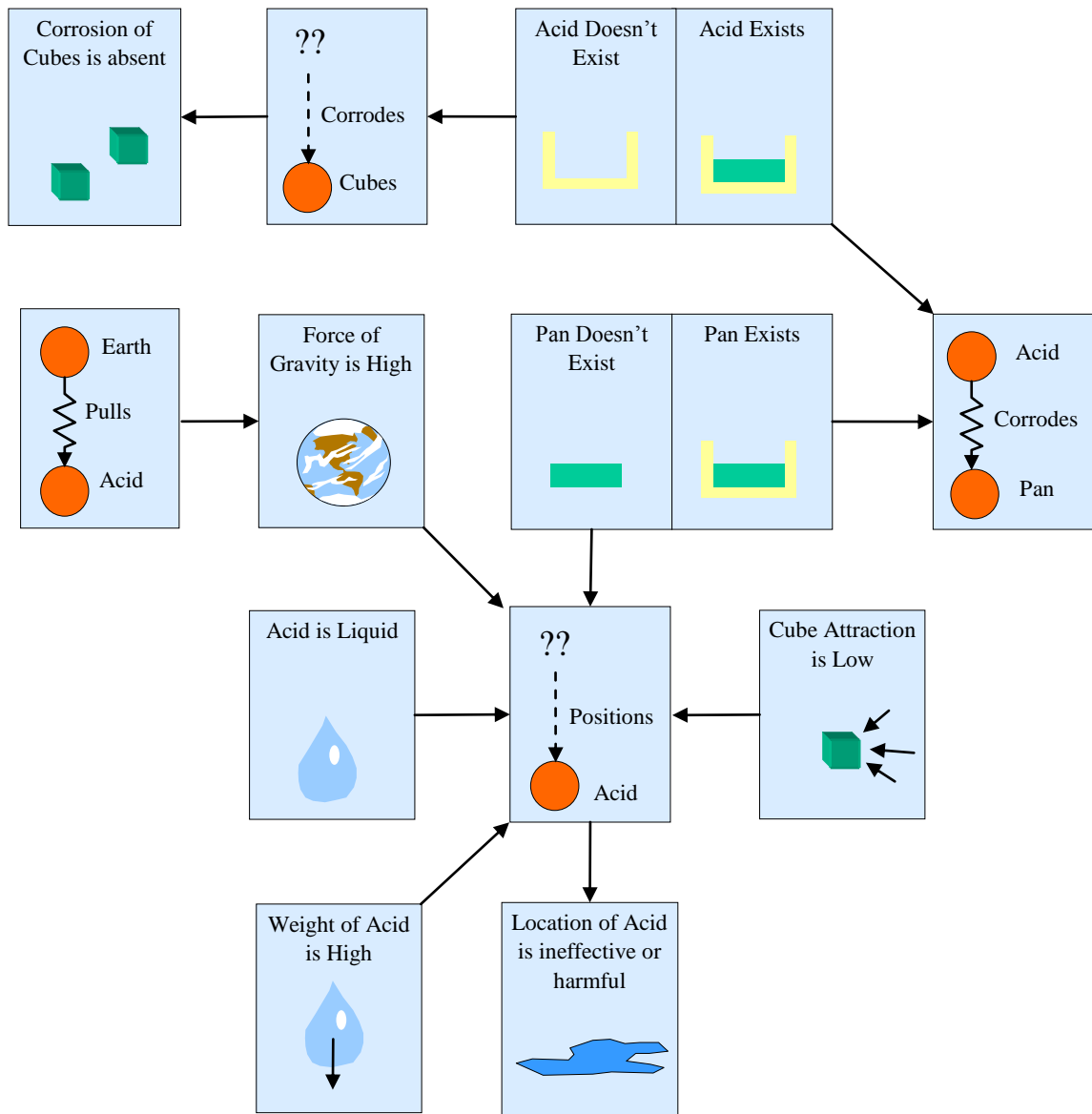
Example—Acid Container

The acid corrodes the cubes but also corrodes an expensive pan that contains the cubes and the acid. We have identified that the pan would be a good item to eliminate since it is related directly to the problem and its loss would completely resolve the problem. Most people would start by looking for materials that are less expensive or ways to reduce the acid damage. This is done without considering that the pan may not be necessary. If we do not require the pan, then we can completely side-step compensating for acid damage. By using the following process, we can find the problem that the pan compensates. If this problem is solved (not compensated) then we remove the necessity for the pan, and potentially other elements of the system.

Go to TRIZ Power Tools—Skill #7—Determining Why Targeted Elements are Required and follow the approaches.

From the diagram, we discover that the cubes are required to position the acid relative to the tubes. If the pan does not exist then we need to find a new way to position the acid relative to the tubes. This becomes the primary subject for the next step. We would like to find a way to position the acid relative to the cubes without the need for using a pan. This problem is a perfect candidate for idealizing useful functions.

This example is given in the book. The following causal diagram is developed.



L2-(Or) Create a Causal Analysis Diagram

Which Should I use: “Full Causal Analysis” or “Why Targeted Elements are Required”?

There are two paths that we could choose here. One way to go is to determine from the ground up what the causes are for the problem. The other path is to determine why the elements targeted for elimination are required. It is possible that by eliminating elements in the system that the problem will go away and we will not have to expend the work of a full causal analysis. This means that we may not have to understand all of the causes of the problem. On the other hand, some problems are very complex and a full causal analysis is required to understand how things work. A good example that was related to the author is related to pilot actions in cockpits. The function of a pilot and the rationale for actions can be very complex. Removing elements from a system without a full understanding of the unintended consequences can be disastrous! At one time, the author chose to begin all problem solving with an in-depth causal analysis.

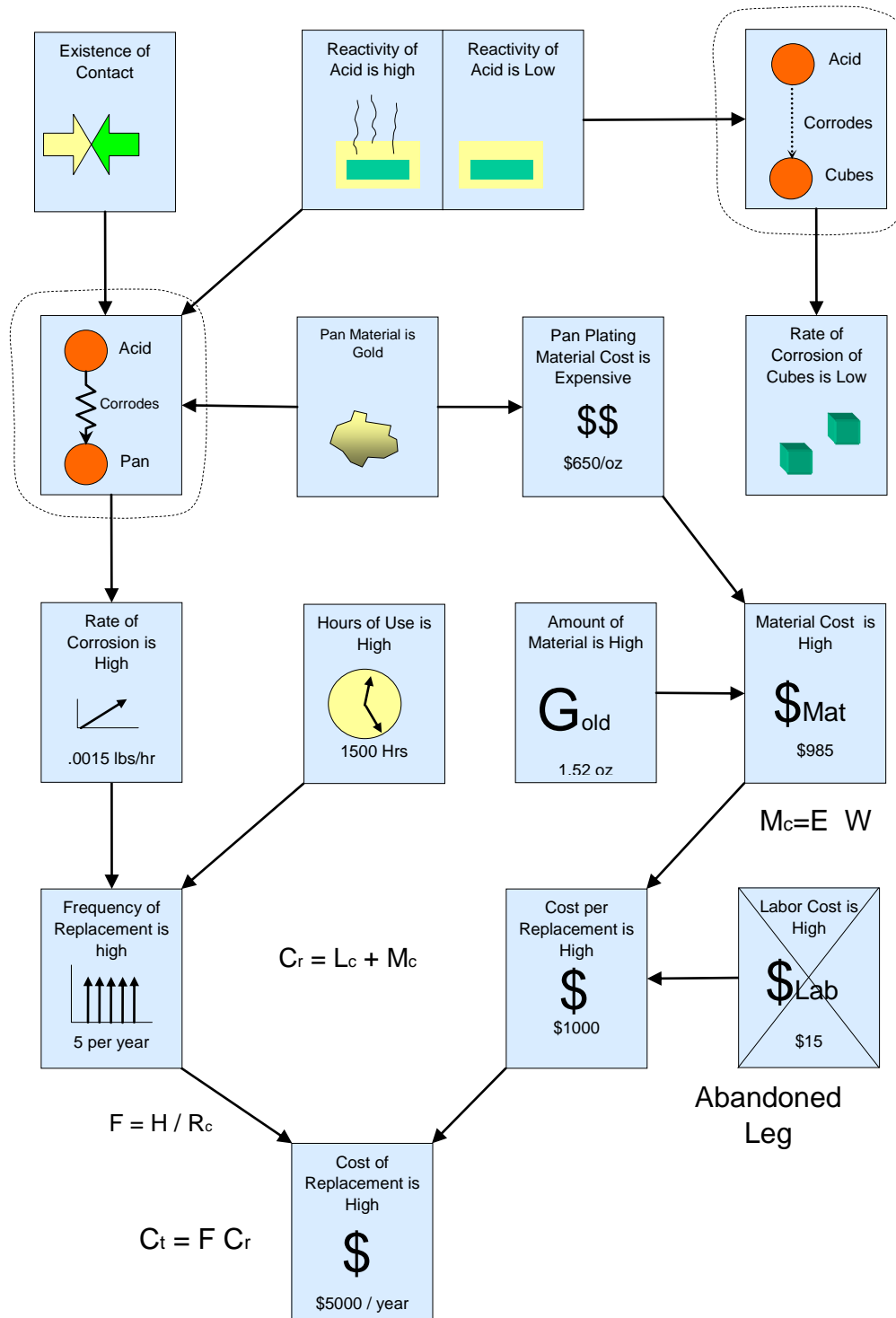
L2-Method

Go to TRIZ Power Tools Skill #6 Discovering Cause and perform the required steps.

Example—Corrosion of Acid & Cube Container

Go to TRIZ Power Tools Skill #6 Discovering Cause and perform the required steps.

On the following page is a pared down version of the causal analysis diagram. Note that in this example we did not show the methods used in determining why elements are required. Since existence of objects are parameters or knobs of every function, we could have come to the same conclusion that we did in the book *TRIZ Power Tools –Skill #7 Determining Why Targeted Objects are Required*. But, as stated in this book, this is a causal analysis shortcut that can get us to the heart of the problem faster and it often does not require us to go to the level of understanding the physics that the full causal analysis requires. Let this be a lesson: try to first determine why problematic elements are required.

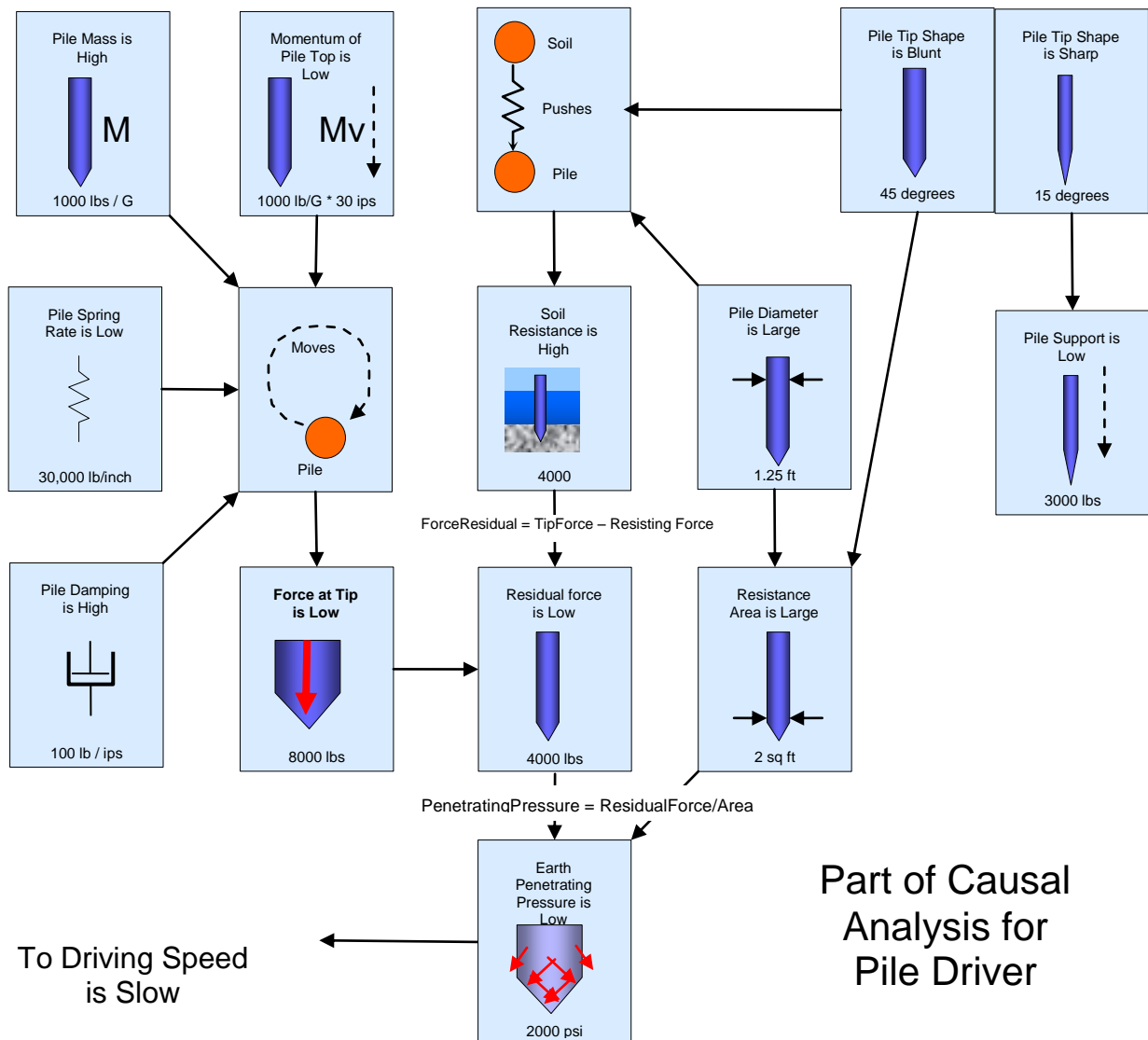


Example—Pile Driving

Go to TRIZ Power Tools Skill #6 Discovering Cause and perform the required steps.

Please accept apologies for the low fidelity of the following diagram. There are a number of physics short-cuts that would not be there had the space been available. The point is to show some of the physics that we will use later. Contradictions could have been shown for the pile mass, pile diameter, pile damping, etc. The only one shown is for the tip angle which will be used later.

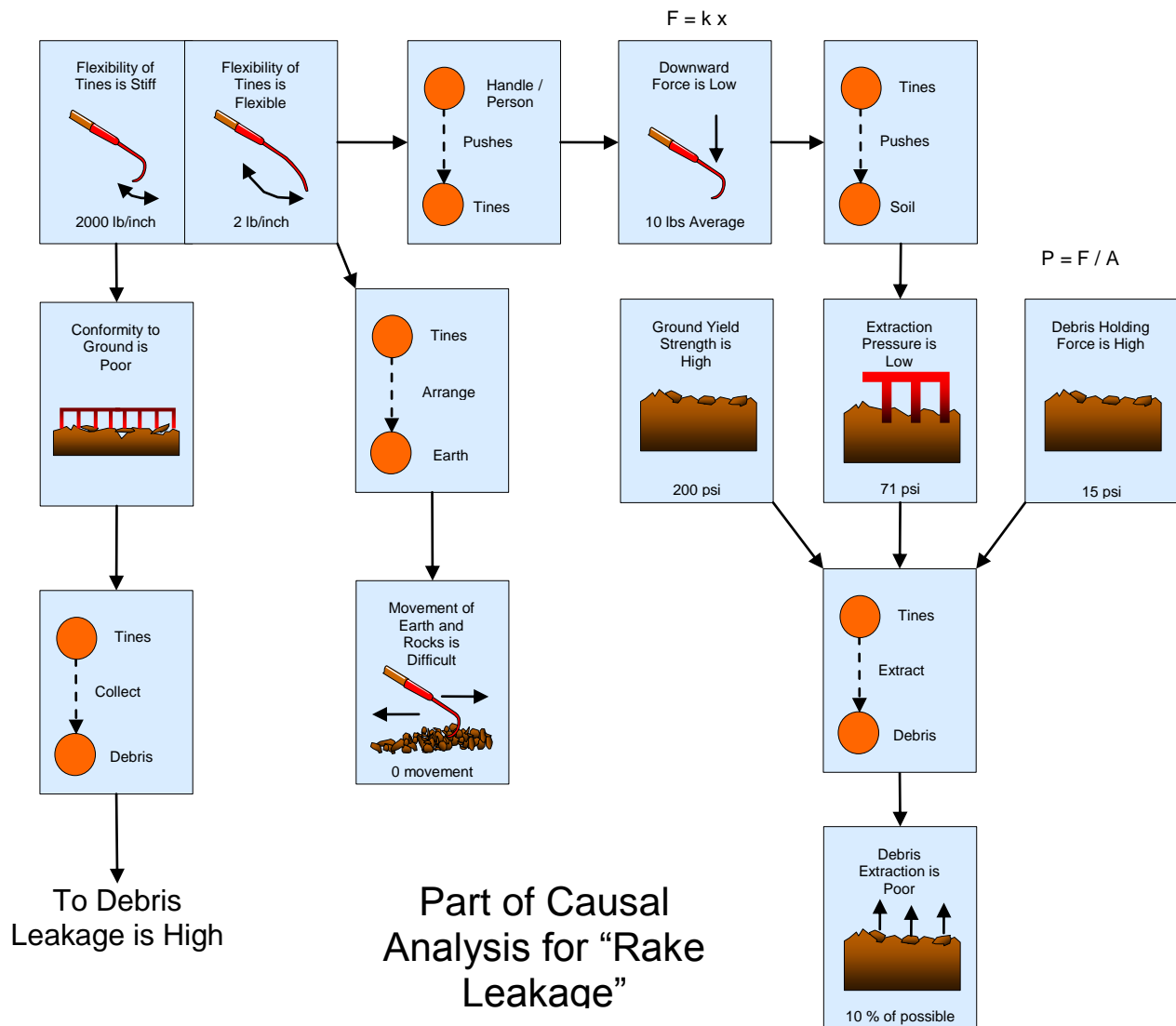
Not shown is the momentum of the pile driver being transferred into the top of the pile. The pile is treated as a spring-mass-damper system in series. The momentum of the pile driver is transferred to the top of the pile.



Example—Rake Debris Leakage

Go to TRIZ Power Tools Skill #6 Discovering Cause and perform the required steps.

Following is a pared down version of the causal analysis diagram. The primary function that we are going to focus on is the function of collecting the debris and the difficulty that the tines have to conform to the surface of the ground. We note that the primary reason that the tines cannot conform to the ground is that they are very stiff. The debris moves under the tines



L1-Solve by Idealizing Problematic Functions

Simplicity is the ultimate sophistication.

~Leonardo DaVinci

A Definition of Idealizing Functions

We want the base problem is completely resolved at the same time, we want to *remove the most elements from the system*. This is accomplished by making the functional elements (product, tool and modification) as ideal as possible. In order to do this, we may need to jump to a new system or, at least, remove elements from our system. We are deciding which functional elements we want, before we decide on their attributes. This is an unusual thought process, but we will see that it unleashes unusual thoughts.

Solutions Should Simplify

We have just performed a causal analysis. Like a good doctor, we have tried to understand the cause of the malady from the symptoms which are rarely the problem. A doctor searching for the cause of a disease is a good example of causal analysis. Unfortunately, when it comes to identifying a solution doctors are a bad example because they will attempt to preserve as much of the patient as possible. This is in stark contrast to what we need to do with technical systems. We want to preserve the *least* amount of the “patient” as possible without reducing performance or other important features.

Technical systems impose human burdens. If properly performed, radical surgery can remove these burdens while preserving the critical attributes. This is the hallmark of TRIZ solutions and of all good designs. The second axiom of Axiomatic Design⁹ tells us that good designs impose the fewest requirements for information exchanges. In other words, good designs require fewer functions and are therefore more simple. Regardless of what we do, either the system or super-system should become simpler. (This means that it is fine for the system to become more complex if the super-system (Job) becomes less complex).

To Jump or not to Jump

Radical surgery can come in two forms. Either remove elements of the current system or jump to a new system by replacing elements with new technologies. The decision to jump to a new system rather than simplifying the current system is based upon the constraints for solving the problem. Remember that when we determined the problem scope, we considered the constraints on the problem solving process such as how much time and budget we had to work with. We also considered how many alternatives we needed to generate. From these, we get a pretty good idea how much we will be allowed to change the system.

⁹ Suh Nam Pyo of MIT, *The Principles of Design*, Oxford University Press, 1990,

When we jump to a new system, we typically replace elements in the system with new technology. This usually results in unanticipated problems. We should keep this in mind if finding the solution has a short fuse. There are exceptions to this rule, but we cannot know beforehand whether we will be the rule or the exception.

On the other hand, removing flawed elements from our system *is often* worth the additional problem solving time, *even if there is little time to solve the problem*. Simplification can remove multiple problems including the one that we are faced with. We have just done a causal analysis. We understand why everything is needed in the system. Often, objects related to the problem are only required because something else is not doing its job. It may not be doing its job because of a problem hidden in the system that has not been solved. If we solve this problem, the requirement for other elements may go away. *The system becomes simpler at the same time that we are improving it*. This is elegance.

Ideal Results and Machines

Jumping to a new system is not simply brainstorming new technologies. There is a better way: we must work backwards. To make this point, Altshuller presents a problem posed by D. Poia.¹⁰

“How can you bring exactly six liters of water from a river using two buckets, one of four liters, the other of nine liters? It is obvious that pouring water “by guessing” from one bucket to the other is prohibited. The problem has to be solved using the exact measuring capacity of the two buckets.

I offered this problem to students at seminars before we began to study the methodology of searching for a solution. The results never differed from Poia’s conclusion. Attempts to solve the problem without our systematical approach looked like this: “What if we do this?” The correct solution appeared after many “what ifs.”

Altshuller compares this to the way that technical problems are often solved, by starting with a mental image of familiar machines and then trying many “what ifs” to improve it. Eventually, a solution is reached, but after many trials. This method ultimately leads to solutions that resemble the starting point with added complexity. He then suggests that there is a better way to solve problems that require guess work: namely, *start with the solution and work backwards*. Altshuller then applies this to the water bucket problem.

“It is required that one of the buckets contains six liters. Obviously this could only be the large bucket. So, an Ideal Final Result would be to have the large bucket filled with six liters.

For that, it is necessary to fill the large bucket (with a capacity of nine liters), and then pour out three liters. If the second bucket had a capacity of three—rather than four—liters, the problem would immediately be solved. However, the second bucket has a four-liter capacity. To make it a three-liter bucket requires filling it in advance with one liter. Then it becomes possible to pour three liters out of the large bucket.

Therefore, the original problem is now reduced to another, much easier one: Measure one liter of water with the help of the two existing pails. This creates no difficulty because $9 - (4+4) = 1$.

¹⁰ Genrich Altshuller, The Innovation Algorithm, Technical Innovation Center, Page 127

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We can fill the large bucket and then pour out four liters twice into the small bucket. After that, one liter of water will be left in the large bucket. We can now dump that one liter into the empty small bucket.

The four-liter bucket now “becomes” a three-liter bucket—exactly what we need. We fill the large bucket once more to its rim, and then pour off three liters into the small bucket. Six liters of water will now be left in the large bucket. The problem is solved.

Altshuller goes on to state that the pattern of starting with an ideal solution and working backwards can be extended to solving inventive problems. One must start with a model of a preferred final state and then proceed by improving upon this model. In essence, this is how we jump to a new system.

“If an inventor starts by stating an *Ideal Final Result*, then an *ideal* concept is taken as the basic model. This model is now already simplified and improved. Further mental experiments will not be aggravated by a burden of habitual mental forms. These experiments immediately get the best perspective for their direction: The inventor tries to reach the highest results by the least means possible.”¹¹

The idea of starting with a model of an ideal solution is often used unconsciously by successful inventors.

How Many Ideal Final States Do we Need?

In the above dialogue, Altshuller referred to an Ideal Final Result (IFR). If you have studied TRIZ, it is very likely that you have been exposed to this concept. Over the years, the concept of the Ideal Final Result has changed and become more specialized, especially as it relates to contemporary ARIZ¹². Nevertheless, there has always been a quest to identify at least one ideal final state that would serve as a guide post to the problem solver or inventor. The idea was that the problem solver should never give up on achieving this ideal final state. Letting go of this vision of the final state would lead down perilous paths.

Early TRIZ theorists and practitioners strove for a “best way” to represent *the* final state. As an example, Altshuller poses “the” IFR for a situation which involves painting the inside of a pipe.¹³

“If, for instance, we are talking about a device to paint the internal surface of a pipe ...*The ideal result, in this case, must be formulated differently: “Paint comes by-itself into a tube and by-itself evenly covers the tube’s internal surface.”*” (Italics added).

Notice that this formulation precludes *other* final states which are potentially *more ideal*. For instance, what if the pipe does not require painting at all or it comes already painted? *These are also viable solution paths*. If Altshuller had only considered the condition that the painting was not required, he would then be precluding the less ideal state of the paint coming inside the tube by itself. Either state is much more ideal than the starting system that required

¹¹ Genrich Altshuller, The Innovation Algorithm, Technical Innovation Center, Page 128

¹² ARIZ refers to the Algorithm for the Solution of Inventive Problems. Altshuller and his associates created different versions through the years. The most recent being ARIZ-85c. 85 refers to the year it was formalized and c refers to the revision. ARIZ is a structured way to expose and resolve conflicts in systems and to apply the basic tools of TRIZ to solve problems.

¹³ Genrich Altshuller, The Innovation Algorithm, Technical Innovation Center, page 129

humans to paint the inside of a pipe. The conclusion is that there may be multiple states which are far more ideal than the starting state of the system. However, these states are not equal. Each has to be judged on its own merits, given the situation and the limitations on solving the problem.

This highlights an interesting question for TRIZ theorists. Is there an advantage to having multiple “ideal” paths in which some are more ideal than others? As solution paths proliferate, some TRIZ theorists become uncomfortable. Some would say that this puts us back to the state of having many solution paths and ultimately many options to pick from, which seems uncomfortably close to trial and error problem solving.

The conclusion of this text is that multiple “ideal” paths are allowable if not necessary. The need for multiple solution paths comes from a practical aspect of solving problems and inventing. *We cannot know what problems must be confronted as we continue down any particular solution path.* For instance, it may turn out that manufacturing the tube such that it does not require painting might require a lot of research into material corrosion. We may feel confident that with our skills, the solution will ultimately be reached, but the availability of time and money resources could doom this research-based approach! It might turn out that using paint on the inside of the tube is very acceptable and will keep the initial problem at bay for many years.

Define “Simpler”

In order to lay the groundwork for some definitions, it is important that we can see the concept of simplicity on different levels. In the text, when we talk about how simple or complex a system is, we are generally referring to the number of functional objects in a system. Functional objects are object groups that modify other object groups. We have already talked about functions and their importance in system modeling. When we describe a system as being complex, we are generally stating that there are a lot of objects and more specifically, there are more functions. When we jump to a simpler system, we are envisioning a system that has fewer functions and consequently, parts or objects.

As a note of warning, once we achieve fewer objects, we then want to idealize the object parameters to get the most out of these objects. Interestingly, the object’s parameters may become less simple to manufacture in order to achieve the highest level functionality. For instance, the objects may become asymmetric and therefore more difficult to manufacture. We can pick up an object such as a cube and say that it is more “simple” than a prism. In this case, what we mean is that it is usually easier to make a cube than a prism, although a prism may have fewer surfaces. Rods are simpler to manufacture than cones. In each of these cases, we are referring to the simplicity of reproducing object parameters. However, this type of simplicity is not what we are talking about when we refer to the complexity of a system. We are referring to the number of functions required by the system to get a job done.

We should also note that there are times that our system will necessarily become more complex. This seems to break the rule that simple is better. It is sometimes necessary to make a system more complex in order to make the super-system (job) simpler. This helps to explain the cyclic nature of system complexity where systems become more and more complex before something happens to drive the system to fewer consolidated objects. We should not chalk this up to poor designs, especially if they survive. It is more likely that the added complexity makes the super-system more simple in some way. On the whole, the world should be simpler when we are done. We can systematically accomplish this by first simplifying the super-system and then its sub-systems. This is the subject of another book and will not be considered further here.

A Structured Approach to Simplifying: Idealizing Functions

In the introduction to this series of books, the concept of a Hierarchy of Decisions was introduced. One part of this hierarchy is repeated over and over, the idealization of functions. Whether we are creating a system, overhauling a system or fixing a problem with the system, we use tools to focus in on one function at a time. When we create a

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system, we add a function at a time. When we overhaul the system, we identify burdensome functions that must be changed. In each case, we are focusing on a function which we would like to make as ideal as possible.

Functions state changes that occur in time or *results*. If we use a function to describe the final state of an object's attributes, then we are describing a "result". If we are describing an ideal result, then we are describing an idealized function. Just as a method can be proposed to work the bucket problem backward, so a path is proposed to work backwards from the ideal final state of an inventive situation. This is effectively accomplished in the following steps for idealizing a useful function:

Step 1: Identify an ideal product.

Step 2: Identify an ideal modification (Step 1 and 2 give the ideal result. The path to this result is stated in the next two steps).

Step 3: Identify potential ideal physical phenomena to deliver the function.

Step 4: Identify an ideal tool to deliver the physical phenomena. (This completes the traditional IFR by stating a means to the ideal result.)

Step 5: Idealize the Attributes of the Objects and Fields. (Now we start to consider the ideal attributes of new objects. When we added objects for the product and tool, we created mental models of these parts of the system. This added problems that now need to be addressed.)

Step 6: Resolve the resulting contradictions. (This step considers the ideal distribution of the properties of the object, further solidifying mental images of the system into more ideal states).

These steps are for working with useful functions. The order is changed somewhat for working with informing and harmful functions.

It is notable that many of the Solution Standards and other TRIZ tools were already stated in functional language. Suggestions for how we might find a more ideal functional part come from a restructuring and reinterpretation of the parts of the Solution Standards that deal with eliminating, redefining or replacing system parts (object resources). Idealizing Functions is the convergence the Ideal Final Result, Function Analysis, and the Solution Standards. Thus, there is a ready supply of approaches to describe the final state.

What about Beginners?

We have just finished a causal analysis. Perhaps obvious solutions have become apparent. It is natural want to start solving the problem by "turning knobs". This is fine for beginners that are uncomfortable working with functions, but remember that jumping to a new system can be a very powerful way to solve problems. Since jumping to a new system involves working with functions, you should be comfortable with functions. If you are a beginner, consider reviewing the chapter which describes working with functions. When you are ready, come back and start the problem solving process here, rather than resolving contradictions.

Whatever systems we create in this section are further evolved when we go to resolving contradictions. This means that if we decide to skip this step and go to evolving the current system, everything will still be in order. Whatever system that we come up with needs to be evolved to a practical stage. This means that it must meet all of the requirements for the product or process.

L1-Method

Step 1: Pick a useful, informing or harmful function that needs to be improved

Step 2: If the function is useful: Look for ways to avoid performing the function in the first place. Find out why the offending parts are needed. Remove the need for these parts. Find a way to avoid needing the offending parts by reversing the situation or doing things at a different time. Consider using a different physical phenomenon that does not require the offending parts. Consider simply removing one of the offending elements and allowing other elements of the system or the surrounding system to take over their useful function.

Step 3: If the function is a informing (measurement or detection) problem: Look for ways that the observer is not required. Look for ways to avoid measurement such as pre-measurement. Find out why the measurement is required and remove the reason. Consider using a different physical phenomenon that does not require the offending parts. Consider ways to put a substance or field in the detected object and measuring that instead.

Step 4: If the function is harmful: Find out why the harming parts are needed and then remove the need for these parts. If the harming part is a system tool that performs a useful function then remove the tool and find something else in the system to perform the function.

Example—Acid Container

Step 1: Pick a useful, informing or harmful function that needs to be improved

From the foregoing analysis we pick the positioning of the acid. We recognize that if we can find an alternative way to position the acid, then our problem will go away. We could have chosen the function of the cube informing the experimenter as to the level of corrosion of the cube. From the causal analysis, we could also have chosen the corrosion of the pan by the acid. For the purposes of learning, we will consider each of these functions.

Step 2: If the function is useful: Look for ways to avoid performing the function in the first place. Find out why the offending parts are needed. Remove the need for these parts. Find a way to avoid needing the offending parts by reversing the situation or doing things at a different time. Consider using a different physical phenomenon that does not require the offending parts. Consider simply removing one of the offending elements and allowing other elements of the system or the surrounding system to take over their useful function.

The function of positioning the acid relative to the cubes is useful. Now, we look for a way to avoid performing the function in the first place. Perhaps we could avoid performing the function if there were another way to corrode the cubes other than liquid acid. This does not yield useful results. Next, we ask why the offending parts are needed. The pan is required to position the acid relative to the cubes. If we no longer need to position the acid then there is no need for the pan. It is determined that we still need to position the acid in some way. Next, we try to find a way to avoid needing the offending parts by reversing the situation. Instead of position the acid relative to the cubes, perhaps we position the cubes relative to the acid. In this case, we might want to suspend the cubes part way into the acid. Then the problem is reduced to one of

controlling the position of acid. This does not yield useful results. Doing the corroding or the positioning at a different time does not yield results. Considering a different physical phenomena to position the acid leads us to the possibility of positioning the acid as a foam or using gravity to position the acid. This goes well with the idea of allowing other system elements to take over the job of positioning the acid. In this case, the cubes, themselves take over the positioning of the acid.

Step 3: If the function is a informing (measurement or detection) problem: Look for ways that the observer is not required. Look for ways to avoid measurement such as pre-measurement. Find out why the measurement is required and remove the reason. Consider using a different physical phenomenon that does not require the offending parts. Consider ways to put a substance or field in the detected object and measuring that instead.

Had we chosen the detecting of corrosion of the cubes then our first task would be to find a way that the observer is not required. This is very specific to the question of why we are corroding the cubes. Perhaps the reasons are limited and it really does not need to be performed. Assuming that measurement of corrosion is required then we look for ways to avoid measurement such as pre-measurement. Pre-measurement usually occurs when we need to measure out specific amounts of something before-hand, which we do not need to do in this case. If we knew that the measurement of the corrosion was required because of a problem elsewhere, perhaps we could attack this problem instead. In looking at different ways to detect the corrosion, it might be possible to identify a more sensitive measurement system which requires a much shorter time in the acid.

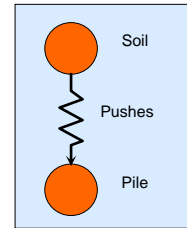
Step 4: If the function is harmful: Find out why the harming parts are needed and then remove the need for these parts. If the harming part is a system tool that performs a useful function then remove the tool that causes the harm and find something else in the system to perform the function. Look for a useful variant of the harmful function and then boost the useful function. Divert the harm to an added expendable object. Put a mediator between the harming object and the object being harmed which is made of a substance which is a modification of the substance of the harming or harmed object.

For this example, we considered the harm that the acid is performing on the pan. First, we look for why the acid is needed to corrode the cubes. The cubes are being corroded to study the effect of a variety of acids on metals. This is a primary function and it is performed for a variety of reasons so we will not challenge this. Next, we consider simply removing the acid and replacing it with something else in the system that can perform the same functions. In this case there is nothing else in the system but part of the acid that could perform the function. Not being a chemist, I ask myself what part of the acid does the corroding? Does the H^+ ion be created in sufficient abundance in another way to perform the function? Can it be sufficiently concentrated on the metal? Next, we ask if there is a useful variant of corroding. A useful variant of corroding would be forming. How can the acid be used to form the pan? Since the form of the pan is not that important, this line of reasoning is not particularly useful. Next we ask if we can put a mediator between the pan and the acid. The mediator should be a modification of either the pan or acid substance. One possibility is to use the solid version of the acid as the mediator. If it could be formed into a sufficiently dense shape then it could hold the acid and the pan would not be harmed.

Example—Pile Driving

Step 1: Pick a useful, informing or harmful function that needs to be improved

We will assume that the function of the pile driver driving the pile has already been taken to the limit and the most powerful driver available is used. We could focus on getting the most energy to the tip of the pile or we could concentrate on reducing the resistance of the soil to the pile. At this point, there is no apparent advantage for idealizing either function. Since we could take either path, we will take one that is instructional for processes that will come downstream, namely mobilizing resources and resolving contradictions.



Step 2: If the function is useful: Look for ways to avoid performing the function in the first place. Find out why the offending parts are needed. Remove the need for these parts. Find a way to avoid needing the offending parts by reversing the situation or doing things at a different time. Consider using a different physical phenomenon that does not require the offending parts. Consider simply removing one of the offending elements and allowing other elements of the system or the surrounding system to take over their useful function.

Since this is not a useful function, step 2 does not apply.

Step 3: If the function is a informing (measurement or detection) problem: Look for ways that the observer is not required. Look for ways to avoid measurement such as pre-measurement. Find out why the measurement is required and remove the reason. Consider using a different physical phenomenon that does not require the offending parts. Consider ways to put a substance or field in the detected object and measuring that instead.

Since this is not an informing function, step3 does not apply.

Step 4: If the function is harmful: Find out why the harming parts are needed and then remove the need for these parts. If the harming part is a system tool that performs a useful function then remove the tool that causes the harm and find something else in the system to perform the function. Look for a useful variant of the harmful function and then boost the useful function. Divert the harm to an added expendable object. Put a mediator between the harming object and the object being harmed which is made of a substance which is a modification of the substance of the harming or harmed object.

First, we realize that the soil is the harming object. The need for the soil is to support the pile the soil is not required at all while driving. If the soil were absent while driving it would be ok. The final result is that the soil is nearly instantly removed and then instantly replaced and compacted in order to make it worthwhile to perform. Removing the soil with an explosion might remove it very rapidly but now we need to find a way to place the explosive at a low depth in sufficient quantity that the explosion would clear the surface. Then we would need a way to put it back very rapidly, perhaps with another explosion. This idea does not yield results.

The next idea also involves removing the soil. In this case we would be looking for something that performed the same supporting function of the soil. Unfortunately, the same issues would be present as with the first idea, we would need to find a way to rapidly remove the soil and replace it again. This line of reasoning does not yield results.

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Next, we look for a useful variant of the harmful function of pushing the pile. It is ironic that a useful variant of pushing is supporting. Supporting the pile is what the soil will ultimately do, it is just doing it too early! In this case, we are not going to drive the piles, but rather boost their ability to support the structure without driving. This embryonic idea must support vertical and lateral loads and must be impervious to the movement of water since it is supporting a structure just off the shore. In effect, we are increasing the ability of the soil to support rather than the ability of the pile to be driven rapidly. The pile driver is now out of the picture and new methods are required to make the soil suitable for supporting and attaching to the pile. Finding the right knobs to turn would be considered in the next section on mobilizing idle functional resources.

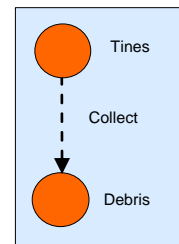
Next, we consider diverting the harmful action to another expendable object. This means that the soil pushes on another object rather than the pile. Usually, this is used if an object is causing permanent harm. In our case, the harm is not permanent, it only occurs during driving. The author cannot find a way to make this work.

The final approach is to use a mediator between the soil and the pile that is a modification of either the pile or the soil. If the soil is saturated with water then the water can become the modification between the pile and the soil. The force against the pile grows at greater depths due to the weight of the soil. Since the density of the soil is much greater than water at the same depth, water pumped to that level might liquefy the soil enough to decrease the pressure forcing against the pile. This would require a way for the water to be introduced at the interface between the pile and the soil.

Example—Rake Debris Leakage

Step 1: Pick a useful, informing or harmful function that needs to be improved

From the viewpoint of the rake manufacturer, we will focus on is the function of collecting the debris and the difficulty that the tines have to conform to the surface of the ground.



Step 2: If the function is useful: Look for ways to avoid performing the function in the first place. Find out why the offending parts are needed. Remove the need for these parts. Find a way to avoid needing the offending parts by reversing the situation or doing things at a different time. Consider using a different physical phenomenon that does not require the offending parts. Consider simply removing one of the offending elements and allowing other elements of the system or the surrounding system to take over their useful function.

The first option is to avoid collecting the debris in the first place. If you are a rake manufacturer, you are interested in helping the user to collect debris and you want to do this is the most effective way possible. We are not going to choose to avoid this function.

The next approach is to remove the need for the offending parts. If we remove the offensiveness of the debris the function of collecting is not required. The function of the rake is then to change the debris in such a way that it is not objectionable. The thing that makes the debris objectionable is usually that the debris contrasts with the background texture and color. In this case, the “tines” would change their function to one of modifying the texture or color of the debris to become less objectionable. This is an interesting train of thought but one that we will not pursue here.

The next approach is to consider reversing the situation. Reversing the situation requires a little more thought. Normally, the debris is collected to a central location and then

moved into a container for mulching or disposal. The debris is moved relative to the central pile by pulling the bulk of the debris across the ground. If we were to reverse the situation, the pile would be moved to the debris! At first, this seems very inefficient, but let's see an example of this. When one cuts grass, taking up debris at the same time, the pile comes to the debris. Leaf vacuums perform the same function, bringing the pile to the debris. If we apply this to the example of raking, the rake never lets go of the debris. One advantage of this is that the rake does not continue to push the same debris around over soil that has no debris. When a rake normally does this, the risk is that the debris will be redistributed moving beyond the tines onto an area of ground where it was not, before. The efficiency of the operation is much better if the debris is collected once and for all. There is now the added burden of carrying around the weight of the debris. An interesting attribute of this method of collecting is that the efficiency of this type of collection goes up dramatically when the amount of debris per unit area is low. Imagine using a rake to drag a piece of debris ten meters to the next piece of debris and so on until a central collection point is reached. This type of collection is very inefficient using a rake. It would be easier for the collector to bend down and pick up the debris by hand! An example of this type of collection is the mechanical hand collectors used by maintenance people in parks. One piece of debris is picked up and placed into a bag. This type of collection is very inefficient when the number of pieces of debris per unit area is high. For the purposes of this book, we will only consider the condition where a lot of debris is being collected as in the case of a rake with tines. However, we also note that a new idea has been discovered and that is that the movement of debris along the ground allows for the redistribution of already-collected debris. Rather, we should move the collector to the debris if possible. This may be more efficient.

Our next concern is to consider performing it at a different time. From the viewpoint of the consumer, they will want to collect debris at any time that they want, so we won't consider this approach.

When we consider performing the function with a different physical phenomenon or scientific effect, we will assume that we are moving the collection point to the debris. This is the first step of a two-step process. The second step is to move the debris from the ground to the collector. Without the benefit of the scientific effects databases, I am aware of a few ways to move the debris. Here are some possibilities: vacuum, adhesive, electrostatic attraction and mechanically moving the debris. A vacuum requires a fair amount of wasted energy because air needs to be moved at the same time as the debris. The actual movement of debris is not very energy intensive. A reusable adhesive is provided by nature with micro structures found on a gecko's feet. This is not well understood and I don't want to rely on a lengthy scientific investigation unless other methods don't work. The same is true for the use of electrostatic forces. We will consider using something akin to the mechanical tine forces to move the debris into the collector.

The final consideration is to consider removing the tines and replacing it with something else in the system that could perform the function of collecting. No other elements in the system appear to be capable for taking over for the tines.

Step 3: If the function is an informing (measurement or detection) problem: Look for ways that the observer is not required. Look for ways to avoid measurement such as pre-measurement. Find out why the measurement is required and remove the reason. Consider using a different physical phenomenon that does not require the offending parts. Consider ways to put a substance or field in the detected object and measuring that instead.

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Since this is not an informing function, step 3 does not apply.

Step 4: If the function is harmful: Find out why the harming parts are needed and then remove the need for these parts. If the harming part is a system tool that performs a useful function then remove the tool that causes the harm and find something else in the system to perform the function. Look for a useful variant of the harmful function and then boost the useful function. Divert the harm to an added expendable object. Put a mediator between the harming object and the object being harmed which is made of a substance which is a modification of the substance of the harming or harmed object.

Since this is not a harmful function, step 4 does not apply.

L2-Pick the Functions to Idealize

If you have decided to perform a simplified causal analysis, the number of functions will usually be limited and it is likely that all of the functions should be considered.

If you have diagrammed the need for elements targeted for elimination then you have also identified legs of the causal diagram that are strong contributors. Any function (or knob) that lies on the strong path is a strong contributor to the problem. The best ones are functions which, if improved, will solve the problem by themselves. Lower in priority are combinations of functions that have to be improved simultaneously.

If you have performed the full causal analysis, the same approach applies. Look for high impact functions on the strong paths.

By this point, you may have one or several functions. While resolving functions, we idealize functions with the idea of removing elements from our system. We would like to form a rationale that drives us in this direction. (Idealizing functions can be used for other tasks in which we are not concentrating on removing elements. For instance, when we are creating systems, we are looking for ways to deliver functions. In this case, we are adding elements.) When the problem solver has more experience idealizing functions, it will become more obvious in how we strategize a rationale which will remove objects. Hopefully, the examples below will give some insight into the thinking.

L2-Method

Identify useful informing or harmful functions that have the strongest impact on the problem and which show potential for the removal of objects. Form a strategy which drives toward the removal of objects to solve the problem. If a harmful function is on the “strong path” then it is almost always worth idealizing.

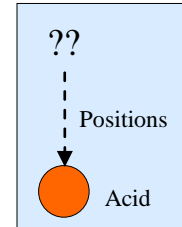
Example—Acid Container

We used the pan corrosion problem to illustrate both forms of causal analysis. The first type that we tried was to determine why elements targeted for elimination were required. It was also used to explain the full causal analysis approach. Neither of these examples was as exhaustive as possible. Had the analysis been more complete, undoubtedly we would have discovered more functions on the strong paths. Such as it is, we will consider only the functions which came from determining the reason that targeted objects are required.

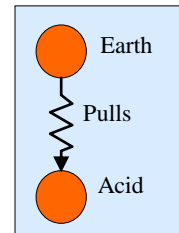
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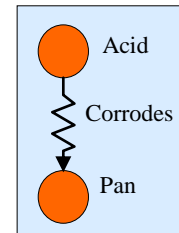
In the causal analysis for determining the reason that targeted objects are required, we identified two objects to target. First, we targeted the pan and identified why it is required. Ultimately, we discovered that the pan was required to position the acid relative to the cubes. If the pan is removed from the system then our problem is solved but now we will need a way to position the acid relative to the pan. If we can position the acid without the use of the expensive pan then our system becomes more ideal and the problem is solved. This is definitely a function that we would like to idealize.



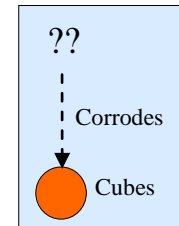
In relation to positioning the acid, we note another function. There is a negative function of the earth pulling the acid. This leads to acid going to places that we don't want it in the absence of a pan. If the earth did not pull on the acid, the problem probably would not exist (so long as the cubes had sufficient force to attract them). When it comes to idealizing or neutralizing harmful functions to solve a problem, it is almost always worth the time. We should also pick this function.



We have another function that is on the strong path. The acid is corroding the pan. If the acid was not corroding the pan then the problem would go away. No question that this is on a strong path. Should we idealize or neutralize this function? Once again, when it comes to harmful functions, it is almost always worth looking at idealizing or neutralizing the harmful function. We will definitely pick this function to try to idealize or neutralize.



There is one final function to consider. The acid performs a useful function of corroding the cubes. If we remove the acid then we need to consider new ways to corrode the cubes. If another way is found, then it may not be necessary to control the position of the acid with the pan. We will also consider this one. One warning on this one. This might require us to perform some scientific investigations which might be time consuming.



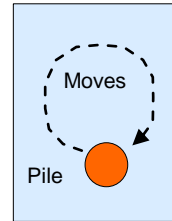
One final word on this example. We can't know beforehand what will come out of the effort to idealize these functions and it really doesn't take that long to idealize each of these functions.

Example—Pile Driving

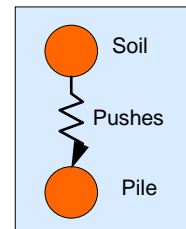
Identify useful informing or harmful functions that have the strongest impact on the problem and which show potential for the removal of objects. Form a strategy which drives toward the removal of objects to solve the problem. If a harmful function is on the “strong path” then it is almost always worth idealizing.

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In spite of the fact that we only conducted a portion of the full-up causal analysis for this problem, we have two functions that we are considering. The first function is the pile penetrating the soil. This is a useful function. With this function, we are concentrating on getting the most energy from the top of the pile to the tip where it penetrates the soil. Notice, however that even getting 100% of the energy from the top to the tip does not solve the problem since the resistance of the soil is so high. While this is an important function, we do not consider it to be on the “strong path”. We will leave this until later. (For the first time around, we would like to focus on functions and knobs that can be used to resolve the problem without involving other functions or knobs).



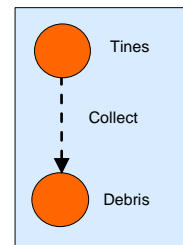
Reducing the resistance force decreases the requirement to get the most energy to the tip. If the soil does not resist the pile then the penetration is very easy and the problem is directly solved. Since this function is on the “strong path” and because all harmful functions on the harmful path are worth trying, we will consider idealizing or neutralizing this harmful function.



Example—Rake Debris Leakage

Identify useful informing or harmful functions that have the strongest impact on the problem and which show potential for the removal of objects. Form a strategy which drives toward the removal of objects to solve the problem. If a harmful function is on the “strong path” then it is almost always worth idealizing.

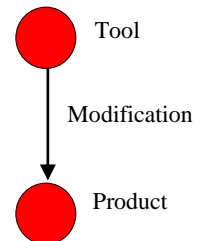
When we look at the causal analysis we note that the only function that we have put on the strong path, so far, is the tine function of collecting the debris. This is partly because the causal analysis can only be partly shown. For instructional purposes, we will focus on idealizing the useful function of collecting the debris.



L2-Idealize Useful Functions

When we idealize functions to solve problems, we are looking for ways to solve the problem by removing the most elements possible from the system. One of the hallmarks of TRIZ is the solution of problems in a way that makes the system simpler. Sometimes we refer to these solutions as “elegant”.

One might ask “Why idealize something that is already useful?” We idealize useful functions, because approaches are given to either avoid performing the function or perform it in ways that require fewer elements. When we eliminate the need for an element, we also remove the need for auxiliary functions which operated on those elements.



L2-Method

Go to the TRIZ Power Tools Book—Skill #3 Idealizing Useful Functions and follow the steps.

Example—Acid Container

Recall that we had two useful functions to idealize. The first was to position the acid. The second was to corrode the cubes. We will first consider the first useful function which is to position the acid.

Go to the TRIZ Power Tools Book—Skill #3 Idealizing Useful Functions and follow the steps.

Ideal product: The acid is still the desired product.

Ideal modification: Positioning of the acid is still desired.

Potential scientific effects include: Using surface adhesion or capillary action, acid foam and gravity

Potential resources include: air, the cubes, powders (including the metal to be tested) porous metals

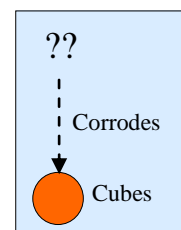
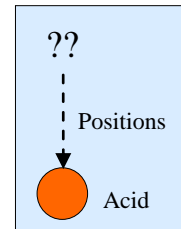
Ideal tool: The cubes are chosen to contain the acid. Form the material that is to be tested into a simple shape that can contain the acid. A round cup shape is probably simpler than a square cube. The cup can then be cut up after corrosion to see the effect of the acid.

Ideal tool: Another possibility is to form the cube into a porous capillary structure that can contain the acid.

Now, let's consider the second useful function which is to corrode the cubes

Go to the TRIZ Power Tools Book—Skill #3 Idealizing Useful Functions and follow the steps.

Ideal product: Corroding the cubes is still the main productive function of the entire acid corrosion system. It is desired that a realistic modification of the cubes by the acid be accomplished. What is interesting is that when we consider how much of the cubes this is necessary. One method ask us to consider modifying the least amount possible. Why do we corrode so much? If the investigation could be conducted on much smaller samples,



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the harm performed could be reduced greatly. This thinking is done all the time when biological specimens are examined. Smaller and smaller samples are taken to reduce the discomfort of the patient.

Ideal modification—ideal level: The least modification possible, the better. The amount that needs to be corroded has to do with the methods that will be used to measure the corrosion. This changes the problem from a corrosion problem to a detection problem.

Ideal modification—ideal duration: The ideal duration makes us wonder how fast the corrosion could occur. What are the limiting factors?

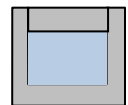
Potential scientific effect: If the temperature is raised to a high enough level, the reaction could occur much faster. In order to do this, the pressure might need to be raised.

Potential scientific effect: The high temperatures and pressures can be accomplished on the micro scale by ultra-sound, without requiring the use of a large furnace.

Potential scientific effect: High voltages might also be considered to increase the rate of the reactions.

Potential resources include: The cubes themselves, ultra-sound and high voltage equipment. High pressure capsules, potentially made from the materials that are being tested, could be used.

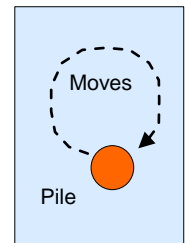
Ideal tool: Enclosing the capsule made of the material to be corroded that then elevating the temperature causes a very high pressure. The high pressures and temperatures greatly increase the corrosion rate and the productivity of the entire system.



These are ideas that we did not have before. There is no real limit to how small the acid capsule can be. Small capsules allow for very high temperatures and pressures. In the end, the amount of the material is greatly reduced and the production of the system is greatly increased.

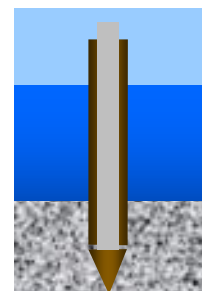
Example—Pile Driving

Recall that the useful function that we want to improve is the function of getting the energy from the top of the pile to the bottom. The pile moves itself. This is because the movement of the tip does not occur instantaneously with the movement of the top. There is a large mass between the top and bottom and it has a low spring rate and high damping. Consequently, a lot of the energy is lost between the top and the tip.



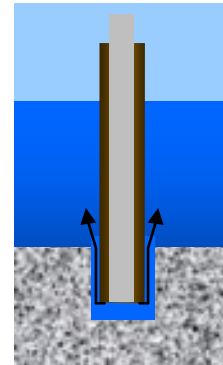
Go to the TRIZ Power Tools Book—Skill #3 Idealizing Useful Functions and follow the steps.

Ideal product—removal of transmission elements: This means that the pile from the tip to the bottom should be removed! At first this seems absurd, but consider that somehow, the pile tip is driven directly by the momentum of the hammer. A couple of interesting possibilities arise. The first is that the pile is hollow and the hammer is a long cylinder weight that is dropped directly on the tip of the pile. As the tip is driven in, the separate pile falls in behind the pile tip which is separate from the rest of the pile. The advantage of this idea is that we no longer have to worry about the weight, spring rate or damping of the pile. All of the



momentum is transferred directly to a stiff tip which has very low mass. The forces generated by this method would be very high.

Ideal product—removal of transmission elements: A second possibility is similar to the first in that the pile is hollow and the hammer is a cylinder that is dropped to the bottom. However, in this case, water is allowed into the tip area. As the hammer drops, tremendous hydraulic forces are created which drive the soil away from the tip and create space for the pile to drop into. The water effectively becomes the tip of the pile. As the driving proceeds, the water at the tip will try to escape between the pile and the soil. This creates a space between the pile and the soil that must be filled after the driving is complete.



Ideal product—removal of transmission elements: A third possibility is that the pile, itself, becomes the hammer and is dropped inside a hollow tube, performing the same actions as the hammer did before. Upon completion of driving, the casing is pulled up, and the soil is allowed to settle around the pile.

Ideal modification: Move the pile tip.

Potential scientific effects include: Hydraulic pressure caused by momentum forces. High tip pressure caused by momentum forces.

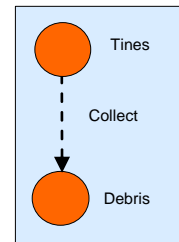
Potential resources include: air, water, soil, the pile itself.

Ideal tool: Since the water is in great abundance, water is chosen. It cannot be dulled by the pounding. The pile is used as the hammer so that standard piles do not need to be hollowed out.

Example—Rake Debris Leakage

Go to the TRIZ Power Tools Book—Skill #3 Idealizing Useful Functions and follow the steps.

The function that we are concerned about is the function that the tines perform of collecting the debris. This is problematic because the debris tends to easily move under or between the tines. Also, the act of collecting the debris also tends to spread it.



Ideal product—function no longer required: The debris is somehow modified so that the function of collection is no longer required. This is an interesting possibility. If the debris were modified to be very small, this it might not require movement.

Note that trees that shed small leaves do not require raking. The rake is replaced by a small handheld shredder which segments the debris, in place. While very interesting, this possibility will not be pursued further.

Ideal product—remove the product: Since the debris product is considered waste, the idea that is presented is to change the situation so that the debris is not there. Either remove the debris, the source or the path. While these are possible, we are doing this from the vantage point of a manufacturer that wants to sell rakes. Removing the need for the rake is not the purpose of the manufacturer.

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Ideal product—removing the minimum part: This is intriguing. What is the minimum part of the debris that must be removed in order to achieve the function? Removing small sections of the debris causes it to fall apart. But then, what do you do with the small sections? They can remain in place as well. This takes us back to the idea of shredding or powdering. If we remove an important constituent of the debris that allows it to fall apart, what would it be? If the lightest part, the hydrogen, were removed, all that would be left is the carbon and other minerals which would fall apart. This is also true of the carbon. If I could magically “collect” or remove something, it would be the lighter elements of the debris: the hydrogen which could later be used to power the equipment. If I wanted to completely remove the debris, it would all be oxidized through combustion.

Ideal product—natural groupings: There are certain conditions of debris removal where the debris comes in natural groupings. Leaves dropping under a tree provide a uniform grouping of material to collect. It would be nice if there were some way to remove all of the debris at once.

Ideal modification—variety of modifications: Attraction—If the debris were somehow “attracted” to the pile or the collection point which is carried by the rake, then the leakage and spreading would be greatly reduced. It is not enough to simply move debris along the ground. We need to move the debris up and away from the ground. Using the word “attraction” gives us new ideas on the possible scientific effects that we might use.

Ideal modification—inverse modification: When we considered the Level 1 idealizing of functions, we noticed that the inverse modification might make sense. Here, the pile is moved to the debris. The thinking behind this is that this is done all the time with lawn vacuums and lawn cutting machines. This works so long as the movement of the debris does not cause burden on the user. Thus, we may be trying to attract the debris to the pile that is moved to the debris location. The function is almost identical to a lawn vacuum.

Ideal modification—ideal level of modification: if we are to attract the debris, the ideal level would be from the surface of the ground to the collection point and no further. This probably means that the collection point should be quite low as to allow for the least use of energy.

Ideal modification—ideal duration: this brings up an interesting idea. Often the collection of material does not have to be performed rapidly, especially if the operator is not involved. If the debris magically but slowly moved to a collection point, that would be fine. Conversely, if the collection point moved slowly toward the debris and the debris was “attracted” slowly toward the collection point then this would also be fine. This brings to mind the robotic lawn cutting machines that move very slowly but continuously around the yard. A robotic debris remover could slowly move around a yard as well. We will not pursue this here. If the user is involved, then the duration should be fast enough that the user is not slowed down.

Ideal modification—ideal duty cycle: the duty cycle needs to have a large variability from collecting thick covering of leaves to debris that is more widely separated. If large amounts are available then the collection point should be easily unloaded to prevent excess energy requirements to move the debris around. For instance, assume that the debris is very thick. One swipe may be sufficient to fill the collection point. In this case, it is more ideal to be able to unload the collection chamber into the main collection container.

Ideal modification—ideal use of energy: the energy required is very small to move debris the short distance required. Vacuums, and blades consume large amounts of energy. If possible, these should be avoided.

Summary of Ideal product and modification: Assume that the collection point is being moved to the location of the debris and that the debris is attracted or immediately moved into a collection chamber that is very close to the debris. For now, we want this all to occur with the user present. The device should be able to collect large or small amounts of debris and, if necessary, unload it very quickly. The main question now is how is the debris “attracted” to the “rake” and potentially the collection chamber.

Potential scientific effect: mechanical motion moves the debris into the collection chamber. Examples are moving brushes or tines.

Potential scientific effect: acoustic levitation is capable of lifting objects. The advantage is that all kinds of materials can be levitated. The method requires that a standing wave be formed. What is unknown is how strong this effect is.

Potential scientific effect: adhesives can be used. Of particular interest is adhesives that do not need to be applied such as found on the feet of geckos. This form of adhesion uses amplification of Van Der Waal Forces. Somehow, geckos are able to keep their foot pads clear. If there were other adhesives that could be turned off and on, this would be very useful. This may turn into a research project if this effect is chosen.

Potential scientific effect: capillary adhesion can be used to pick up items. It is also switchable. In my search for switchable adhesion, I came across the following link <https://sites.google.com/site/mikevogelpersonal/home/pnas-secad-news-links> which shows how multiplied points of liquid contact with a solid surface can have a very high adhesive force. The liquid is applied and removed by electro-osmotic flow. Other ways of controlling the droplets can be devised. This has the advantage of using readily available materials such as liquid water. The energy requirements are very low.

Potential scientific effect: electrostatic forces attract the debris to the collection chamber. The potential strength of this effect is not clear. Also, some adjustments might be required for heavy or water-laden items.

Potential scientific effect: vacuums are used on a commercial scale. The forces are sufficient to move large or small amounts of debris, but the energy usage for the actual energy required is extremely high. They are not very efficient in the typical application. If we use this effect, we will need to find a way to be more efficient.

Potential scientific effect: air jets are used on a commercial scale. The forces are sufficient to move large or small amounts of debris, but the energy usage for the actual energy required is high. If we use this effect, we will need to find a way to be more efficient.

Potential resources—adjacent objects and attending fields: air (pressure forces), water (surface tension), electrons (static electricity), PVC (static electricity), humans (human power, blowing, sucking), the debris itself (para-magnetism, inertia, stress forces, gravity),

Potential resources—Cheap abundant substances: Foams

Potential resources—already performed by native fields: wind collects debris, often into piles; gravity also collects debris.

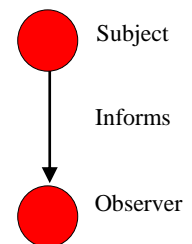
Ideal tool: From all of the forgoing discussion, there are several possibilities which would be desirable if the requirements were different. The requirement to move large amounts of debris at one time leads me away from most of the ideas dealing with adhesion or attraction from a distance due to the lower available forces to move debris in bulk. Also, the attraction must occur while other debris or grass may be holding the

debris to be collected. The desire for low energy consumption moves us away from blowing or suction. Tines are still an abundant resource. Consider that although rakes are a very ancient tool, they continue to be used.

The rationale used to eliminate many of the resources is not perfect. It is possible that means could be provided for boosting or concentrating forces so that they would be more applicable. But, for the purposes of this book, we will go with the forgoing rationale of using tines.

L2-Idealize Informing Functions

Informing functions are a subclass of useful functions. Because the object of measurement informs or modifies the measurement instrument, the object of measurement becomes the most important element of the system. We refer to the tool as the “subject” and the product as the “observer”. This change in priority necessitates a difference in how we deal with informing functions. The book *TRIZ Power Tools—Skill #4 Idealizing Informing Functions* tells us how to deal with informing functions.

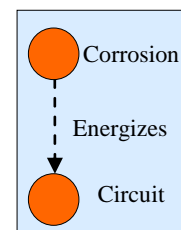


L2-Method

Go to TRIZ Power Tools—Skill #4 Idealizing Informing Functions and follow the Steps.

Example—Acid Container

Recall that while we were idealizing the function of corrosion of the cubes, we questioned the ideal level of the modification. If the amount of corrosion which was necessary could be greatly reduced, then so could the time in the oven. This would also reduce the time in which the acid was corroding the pan. We noted that this would change the problem from one of corrosion to one of detecting the corrosion when very little was formed. We will use this problem to showcase the idealization of informing functions. Let's assume that the amount of corrosion after a short period of time is the item that we need to measure.



This problem began with a measuring corrosion on cubes which are called “coupons” in corrosion literature. The idea is to weigh the coupon to be tested and then corrode the specimen over a period of time. To measure the corrosion, the corroded coupon is cleaned off of all corrosion and then reweighed. The measure of corrosion is then the change in weight over the period of corrosion. By default, this measurement system requires a lot of time, but is quite accurate and allows for variations in corrosion rate over time. It might be useful to perform a final qualification of a material by using this method, but screening tests may be easier to perform if we can find a way to instantaneously measure the corrosion.

For the purposes of this text, we are going to depart a little from the problem at hand and create a situation where we are looking for novel approaches to measure corrosion. If we were just looking for fast ways to measure corrosion, we would likely not go to the depth that we are about to go to.

Go to TRIZ Power Tools—Skill #4 Idealizing Informing Functions and follow the Steps.

The details for this step are found in the above book.

Ideal Subject—one possibility is to only detect part of the corrosion products. For instance, one could detect the volume of gas evolving from the corrosion process.

Ideal Potential Phenomena—The history of corrosion measurement was performed through internet and patent studies. It was decided that it was time to consider new ways to measure corrosion

Ideal Potential Phenomena—Through a variety of approaches, many candidate systems were considered:

- Electrical Resistance (Patents)
- Linear Polarization (Patents)
- Galvanic current (Patents)
- Measure back scatter of beta nuclear radiation (Patents)
- Measure the rate of decay of the potential of the electric double layer (Patents)
- Alternating current impedance (Patents)
- Low frequency noise voltage (Patents)
- MRI (Patents)
- Infrared radiation reflection (Patents)
- Magnetometer measures magnetic fields (Patents)
- Digital imaging (Patents/ products)
- Corrode through multitude elements (Patents)
- Ultrasound (Patents)
- Structural shape of the surface (New)
- Fractal dimension of surface (New)
- Number of active sites (New)
- Interaction site surface area (New)
- Change in coupon weight (Patents)
- Number of voids (New)
- Porosity (New)
- Activity of sites (New)
- Coupon thickness (Patents)
- Height above original surface (Patents)
- Coupon Volume (Inferred from patents)
- Surface density (New)
- Surface Molecular Weight (New)
- Surface Thermal Conductivity (New)
- Surface Thermal Capacity (New)
- Surface Magnetic Permeability (New)
- Surface Magnetic Hysteresis (New)
- Surface Curie Point (New)
- Surface DC impedance (New)
- Surface AC impedance (Inferred from Patents)
- Surface electrical continuity (New)
- Surface Ionization Potential (New)
- Surface Electric Permittivity (New)
- Optical reflectivity (Inferred from Patents)
- Optical emissivity (New)
- Optical absorption (New)
- Optical scattering (New)
- Fringe pattern of reflected light (Patents)

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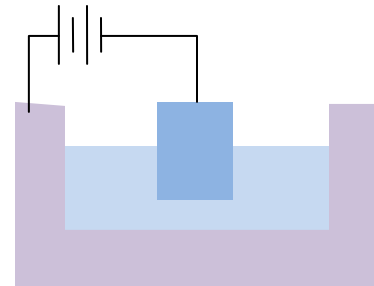
- Difference in digital images (Products)
- Emission from thermal field (New)
- Impedance of skin current (Implied from Products)
- Loss of Isotope (New)
- Photosensitive materials tuned to certain frequencies (New)
- Scatter particles across a non-conductive surface--measure time to loss of continuity (New)
- Resonance of surface currents (Existing Products)
- Measure porosity by evaporation temperature (Library of Effects)
- Capacitance change of the surface (Patents)
- Capacitance from oscillating circuit (Patents)
- Capacitance plus resistance of the corrosion (Patents)
- Capacitance using side-by-side sensing plates (Patents)
- Resonance of corrosion (Patents)
- Scanning Capacitance Microscope (Patents)

Observer Resources—the environment and super-system were examined for substance and field resources that might be used to deliver the informing functions.

Ideal Observer—Finally it was decided that a hybrid a disruptive technology would be combined with the standard coupon method. Electrochemical means of “monitoring” corrosion have been extensively used to monitor corrosion in structures, etc. The laboratory environment has continued to use the coupon corrosion methods. From the viewpoint of corrosion testing in laboratories, electrochemical methods are considered disruptive. These methods have been in existence for some time, but have not had as wide an acceptance as coupon testing.

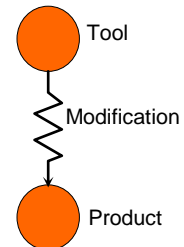
The electrochemical methods have the advantage of rapidly monitoring the corrosion rate and the ability to monitor it to determine when the corrosion becomes stable. Thus, the screening part of the corrosion test is performed. If the sample appears to meet the threshold of goodness then it can be further tested for longer periods of time.

Electrochemical methods generally require the sample to have one electrode (usually the cathode) which is sacrificed. The other electrode then serves as the reference electrode. If we combine this idea with the idea that was generated in Idealizing Useful Functions, then the cathode can be the container in which the acid is contained and the reference electrode can be dipped into it. In some cases, this can be reversed since the anode is not sacrificed.



L2-Idealize Harmful Functions

If the function that you are trying to idealize is a harmful function, then begin here. It may sound somewhat counterintuitive to consider idealizing something that is actually harmful. It would seem to instantly create an oxymoron. For instance, we might find ourselves considering the “ideal pain”, “ideal wear” or “ideal product failure”. While this might sound ridiculous, we shall see that there are ways to think about this that can turn harm on its head. In the end, harm must not exist and might even become useful. The book TRIZ Power Tools—Skill #5 Idealizing and Neutralizing Harmful Functions will describe the approach. When idealizing harmful functions, it is generally more important to prevent than to fix a problem.



Example—Acid Container

Tool Not Required

The acid is required to perform the primary useful function of the testing system which is to test the corrosive properties to liquid acids of varying types. Since this is a requirement of the testing, we must have the acid. This can lead to the contradiction: the acid must exist in order to corrode the coupons and it must not exist in order to not corrode the pan.

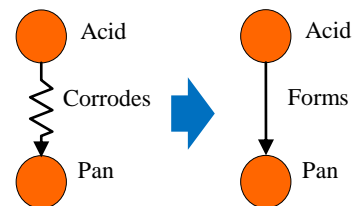
Non-Existent Tool

The acid is simply removed from the system. Something other than the acid must perform the act of corrosion. Since the acid is required in the system and no substitution is allowed, we again end up with the contradiction: The acid must and must not exist in the system.

Reframe as Useful Variant

The harmful action of “corrodes” is reframed to “forms”. So instead of the acid corroding the pan, it forms the pan. In this case, we note that corrosion is usually very non-uniform and thus, the forming of the pan is very non-uniform. If we now consider this to be a useful function then we want to boost this useful function so that the pan material is removed in a uniform manner.

An interesting thought occurs: this is similar to electro-polishing of metallic surfaces which must be performed very precisely. Perhaps if we can understand how electro-polishing is performed, then we may have a potential solution. A web search helps to explain how this is done. One way to form a uniform surface is to always remove the most protruding parts of an object. In order to do this, it is preferable that recesses corrode more slowly than protruding surfaces.



This is done by a process called anodic leveling where the acid electrolyte must be very viscous. The high viscosity of the electrolyte varies the mass transport of reaction products from the surface, effectively limiting the transport of reaction products from lower lying areas of the surface, thus causing protrusions to be removed more rapidly. Additionally, higher electric fields are produced at corners of the objects, thus increasing the mobility of the reacting ions. This implies that it would be necessary to increase the viscosity of the acids. Since the acids must be viscous and the acid that is corroding the

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coupons must be whatever viscosity it comes with, this presents a possible contradiction. The acid must be viscous and non-viscous. One possible way to overcome this contradiction is to cool or freeze the pan which makes the viscosity non-uniform. This additionally will decrease the corrosion rate of the pan.

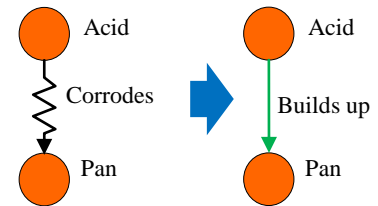
The main knobs are the voltage of the electro-polishing and the viscosity of acid. The easiest to adjust is probably the voltage. The voltage can be adjusted to either protect the pan or to clean it.

One useful function which is performed on the pan is its cleaning. It is possible that the cleaning process performed by humans could be performed by this electro-polishing process.

Reframe as Own Anti Function

Now the acid must build up the pan. Rather than corroding away the pan, we want to build up layers of material.

It occurs that this is a plating process which may occur if we reverse the polarity of the voltage on the pan and introduce a sacrificial material to be corroded away and deposited on the pan.



Reverse the Fields or Action

An interesting thought occurred at this point and a search was performed. It turns out that the driving fields for corrosion can be reversed and the corrosion is stopped. By applying a high enough potential to the pan, we can completely stop the corrosion. Consult the following link.

http://www.efunda.com/materials/corrosion/stopping_corrosion.cfm

The action of corrosion occurs because the molecules of the pan move away from the pan. The reverse would be to move the pan relative to the molecules. This does not yield a useful solution.

Applying a relative voltage or using a sacrificial material will boost the function.

Boost an Existing Weak Variant

This presents an interesting possibility. At a microscopic scale, molecules of the pan are being ripped away by the acid while molecules of the metal are being forced back to the surface. This is true in all chemical reactions. The reason that corrosion occurs is because more material is being pulled from the surface than is being replaced. In this case, replacing more material than is being taken would be the goal. This occurs by reversing the voltage as is mentioned in the approach of reversing the fields.

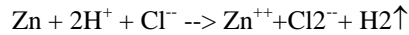
Harmonize Harmful Stages

In this case, we have one main harmful function: the corrosion of the pan by the acid.

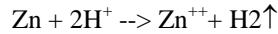
In preparation for examining this harmful function, the author questioned why the chemical explanation for corrosion had not yet been accomplished in this book. What was discovered was that the causal analysis stopped short of the chemistry. We will attempt to remedy this situation by going into the chemistry and explain what is happening. We will then convert this into stages of a corrosion process.

It should be explained that the author, like many readers, is not a chemist or expert in corrosion. As is commonly the case, those who want to solve difficult problems must venture out of their chosen area and study how things work.

Let's consider the case of zinc corrosion in Hydrochloric acid. This explanation can be extended to the material of the pan or the metal coupons under test.

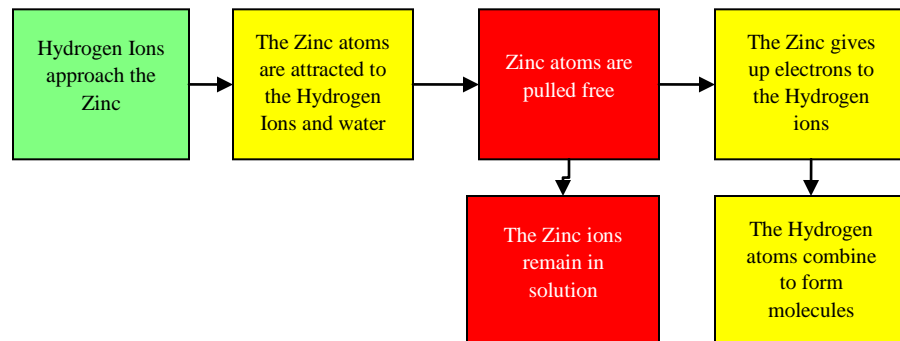


Since the Cl^- shows up on both sides of the equation, we can simplify the equation:

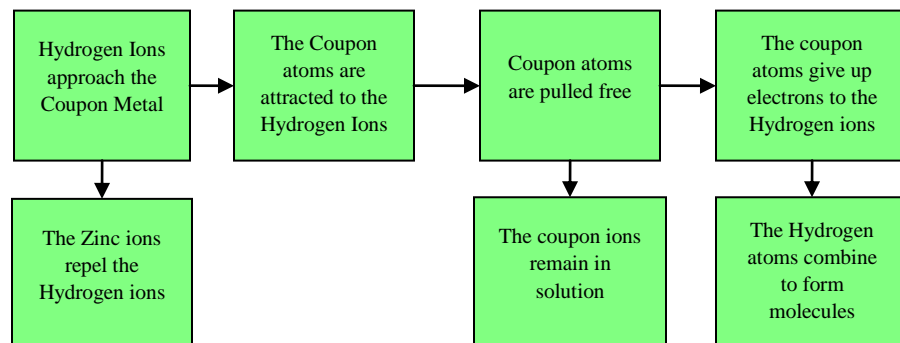


Note that an electron balance is maintained on both sides of the equation, so there is no requirement for current flow, as there is in other types of corrosion. The electrons are transferred from the zinc to the hydrogen and the hydrogen comes off as gas. This shows up as gas bubbles on the surface of the zinc.

The chemistry does not really indicate the sequence of events. Let's hypothesize what happens. As a hydrogen ion approaches the surface of the metal, the positive charge of the ion attracts the loosely attracted valence electrons in the zinc. The zinc atoms are pulled free from the main body of metal by the strong pull of the hydrogen ions (and the polar water molecules). Each zinc atom exchanges two valence electrons with two hydrogen ions. This leaves a net neutral charge on the liquid and the metal and the zinc ions go into solution as zinc chloride. The neutral hydrogen atoms now form into



hydrogen molecules and come out of solution as gas.



For purposes of illustration, let's allow the pan to be made from zinc. The zinc pan contains the acid and coupons. In this case, we want the coupons to be attacked by the

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acid rather than the pan. We allow the tested coupons to give up metal into solution while the zinc repels the ions due to their negative charge. The acid remains net neutral due to the coupon ions replacing the hydrogen ions.

Product Not Required

Weight scales with higher resolution can be easily obtained and a different procedure can be used which requires vastly smaller amounts of acid and cube materials. The materials are more finely divided so that the time at high temperatures is minimized. Corrosion takes place in minutes rather than hours and almost any low-cost container is suitable for containing the acid and sample materials.

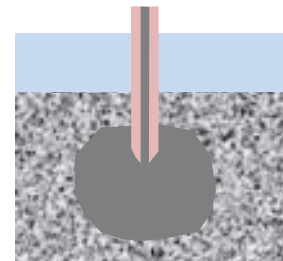
Eliminate the Product

The useful function that the container performed is to hold the acid against the cubes. This will now be performed by the cube itself. The cube is shaped to hold the acid and the container is no longer required.

Example—Pile Driver

Tool Not Required

Most of the pile is not required if a large support structure is placed in the ground. There may be ways to form this structure. For instance, if the pile is driven a distance and then concrete is pumped through it to form a larger underground structure upon which the pile is supported both vertically and laterally. Note, however, if pumping concrete is more time consuming than driving piles, things have only gotten worse since now the operator needs to spend money on more equipment. In order to make this solution more viable, more time is required to remove the bad marks.



Reframe as Useful Variant

The harmful modification of pushing the pile can be reframed as the useful functions of positioning the pile or pulling the pile. The latter useful function of pulling the pile is probably the most ideal. Now the harmful action of pushing the pile is replaced with the useful action of pulling the pile.

The ground must be made to perform a very unnatural act. Already, the pile is pulled down by the force of gravity. In this embodiment, it is not enough for the soil to simply move out of the way and allow gravity to perform its action. We must find a way that the soil, itself, pulls the pile into it.

Note that we no longer consider the methods of idealizing a harmful function. We have switched over to idealizing a useful function. For our purposes, we will bypass the ideal product and modification and ask what physical phenomena are available to deliver the pulling action.

Since the soil is made of many different structures, we can invoke the concept of miniature little people. The soil particles are replaced by intelligent little people that reason and act together to perform the function of pulling the pile into the soil. We can imagine that each little person which is next to the pile grabs hold and pushes down while the people at the tip try to move away from the tip. The particles around the tip must pull each other away and upward. As they move upward, the little people above them must

also move upward. The scene is like a conveyor belt where the soil near the pile is moving downward and the soil which is further from the pile is moving upward and is discharged at the surface. It may be possible to perform this with vibration of the soil or shock waves, but it seems that the action needs to be reflected somewhere around the tip. Perhaps a resonance of the pile might be employed to make this happen. Known technology performs the action of fluidizing the soil around a pile by vibrating the soil. We are considering the additional action of the vibrating soil actually pulling on the pile. Experimentation with this vibration would be necessary to determine whether it could be used to pull the pile into the soil in the way described above.

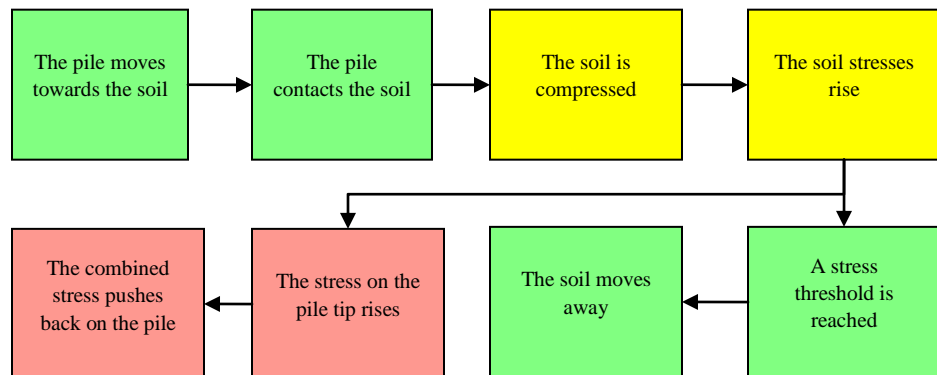
The knobs that control this action are the vibration patterns of the soil. The soil needs to vibrate toward the pile as it moves downward and away from the pile as it moves upwards.

If we could make the soil perform this action, then we might not need the pile driver.

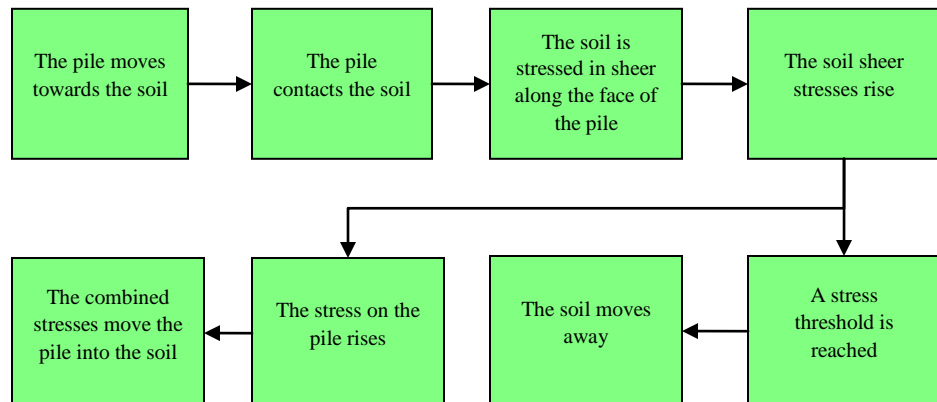
Harmonize Harmful Stages

Let's go back to the function diagram for the pile driver.

We are considering the harmful function of the ground pushing on the pile. Of course, there is an equal and opposite reaction. The pile also pushes on the ground to penetrate it. The pile actually moves the soil and the soil pushes back.



There is an equal and opposite reaction on the pile. The pile needs to move past the soil, but in order for the soil to move, there is a required force or stress that causes it to move. If the pile does not cause it, something else must. For the soil to perform the function of moving itself, there would need to be a tensile force pulling the soil away from the pile.



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The critical place where everything goes south is when the soil is compressed. There are different types of stress that could potentially move the soil including shear and tension stress. But the fact that the pile, itself, creates a compressive stress then requires that the soil pushes back on the pile. Let's say that a shear stress (rather than compressive stress) is created on the soil, but not by the pile. The shear forces are directed along the face of the pile so as to move the soil up and along the surface of the pile. If these forces were created by the pile, then the resulting forces would drive the pile downward rather than upward. This looks like a tractor tread motion that pulls the soil up and away from the pile but also drives the pile into the soil.

Another way is to consider storing the effects. It seems like this means to store the compressive stress on the face of the pile for later use. This relates to some form of stored energy. It occurs that if the compressive stress was stored in such a way that it could be suddenly released with a tremendous amount of energy, then the soil might move more easily.

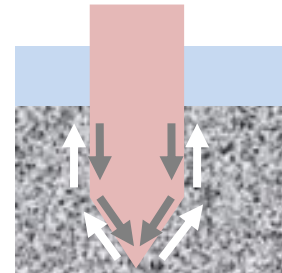
Another way to look at this is to store the energy in cyclic energy. Since the pile is a dynamic spring-mass-damper system, then there is the possibility of storing energy in the spring and the mass of the pile. If the resonant frequency of the pile is achieved, then very high forces are possible.

Product Not Required

The piles are no longer necessary if the structure sits atop something that is at least as interesting as the piles are and has structural soundness. Examples of this would be to transport large boulders and then build the structure on top of the rocks. In our case, this is not good for business because we make money by putting piles into the ground.

Eliminate the Product

Here, we simply eliminate the pile and assume that we will be able to find something else to take the place of the pile. We have already talked about the possibility of using rocks if the pile is eliminated.



L1-Solve by Mobilizing Idle Function Resources

During the causal analysis, you may have discovered parameters of the existing system that could have been used to control harmful or useful effects, but were not. These parameters may show up on the causal analysis diagram because they are a part of the equations. There is no escaping the fact that these parameters enter into the equation of friction, but from the viewpoint of human intent or potential usefulness, they remain idle. The intention of this step is to solve the problem by bringing these features into action. We will do this without reference to what gets worse because we can later remove these problems when we come to resolving contradictions. Our most important mission at this point is to identify idle function resources and put them to work. The book TRIZ Power Tools--Skill # 8 Identifying and Mobilizing Function Resources will provide the approaches for mobilizing idle knobs.

L1-Method

Go to the book TRIZ Power Tools—Skill #8 Identifying and Mobilizing Function Resources and apply the approaches found there.

Example—Acid Container

On the second iteration of solving this problem, it is discovered that containing the acid in the cups requires the cutting of the cups is required in order to study the effect of corrosion on the cubes. This is an extra step that is unwanted. One way to handle this problem is by idealizing the function of cutting the cup. If the cup were to come pre-cut... This is similar to the idea which will follow.

Go to the book TRIZ Power Tools—Skill #8 Identifying and Mobilizing Function Resources and apply the approaches found there.

While going through the list of function resources, the parameter of shape and aspect ratio comes up. The shape of the cup needs to be such that it is easy to look into the cup without cutting it up. It has a flat aspect ratio. In this sense, it comes pre-cut.



L1-Solve by Resolving Contradictions

Resolving Contradictions

At the beginning of this book, we introduced the concept of contradictions while explaining causal analysis. It was explained that resolving contradictions is one of the most useful and fundamental aspects of TRIZ because it greatly expands the solution space. It allows us to consider turning many more knobs than we would normally be allowed to turn. It was explained that resolving contradictions allows us to improve something without making other features worse. At the heart of most contradictions is a knob that must have two settings. We must find a way to turn this knob to both settings. Additionally, we may try the approach of compensating the knob setting of one knob by finding another knob which offsets the effects of the first. All of these approaches can be found in the book TRIZ Power Tools—Skill #1 Resolving Contradictions.

Iterating on Solutions

There are many potential ways to resolve a contradiction and there are many potential solution paths to a problem. Each solution path will bring you to a point where you can visualize an architecture that brings you close to solving your problem. Unfortunately, the perfect solution rarely occurs on the first pass. It is entirely possible that resolving a contradiction will cause other problems. You may recall the problem of measuring the dimensions of a flexible boot. One way to overcome this problem is to resolve the contradiction that the boot must be soft in order to perform its function and it must be hard in order to be accurately measured. One way to resolve this contradiction is to freeze it in liquid nitrogen. This does, in fact, resolve the immediate contradiction, but a new problem arises. The material is distorted by freezing. Note that this problem has nothing to do with the original contradiction. Now we have a new problem that may seem more difficult than the original problem. Rather than abandon the solution, we should continue with this solution path until we are satisfied with the solution. Each solution path may branch many times with the ensuing iterations. This is fine. It is not unusual to have a number of potential solutions. The intention is to continue evolving the solutions as long as it is practical before making a decision. It is not unusual to have several ideas to work on at the same time. In some ways, this creates a state of mind that is very healthy. Rather than focusing in on one idea and sending it to finishing school, you will greatly increase your chances of success by thinking in terms of solution sets.

L1-Method

Go to TRIZ Power Tools—Skill #1 Resolving Contradictions and apply the approaches found there. If the solution causes additional problems, iterate on the solution until any further problems trivial.

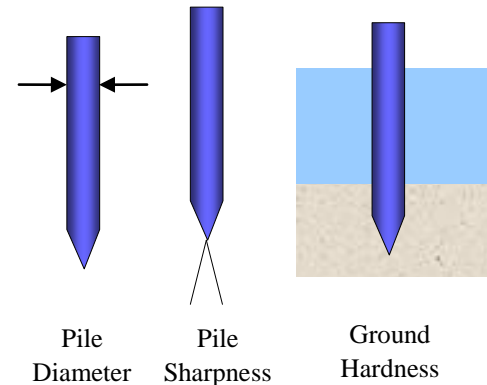
Example—Pile Driving

Pick and Clarify High Impact Contradictions

In this case, there are many knobs which control the driving speed of the pile. Several are mentioned to the right. In this case, we will concentrate on tip sharpness. In order to improve driving speed, the tip must be very sharp. We need to support the structure above under an earthquake load. The contradiction is formed:

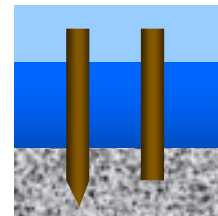
In order to (drive fast) the (pile) (tip shape) must be (sharp)

In order to (support well) the (pile) (tip shape) must be (blunt)



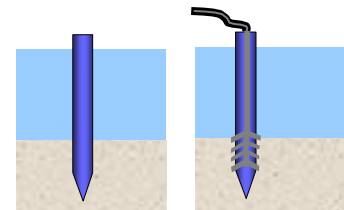
Separation in Time Test

I want the (pile) to be (sharp) while (driving). I want the (pile) to be (blunt) while (supporting). Must the critical conditions overlap in time? This is a clear example of a contradiction where the conditions of driving and supporting are separated by potentially large expanses of time. This is a good candidate for Separation in Time.



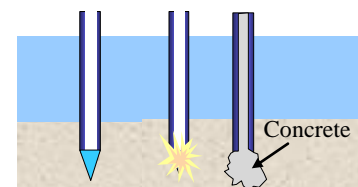
Separation in Time—Carrier—Intermediary

During (supporting) (concrete) which is (blunt) is (attached to) (individual) (piles) which are (sharp) thus loaning its property and making the combination (blunt). No carrier is used during (driving) making the (pile) (sharp). Concrete is pumped into the pile and extrudes out holes, making the pile BLUNT.



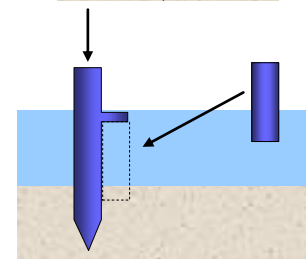
Separation in Time—Carrier—Intermediary

During (supporting) (a concrete bulb) which is (blunt) is (attached to) (individual) (piles) which are (blunt) thus loaning its property and making the combination (blunt). No carrier is used during (driving) making the (pile) (blunt). First, the pile is SHARP for driving. Later the tip of the pile is exploded and concrete is pumped into the resulting cavity. The concrete carries the property of bluntness and makes the whole pile BLUNT.



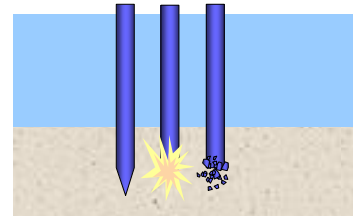
Separation in Time—Carrier—Intermediary

During (supporting) (a blunt pile) which is (blunt) is (attached to) (individual) (piles) which are (sharp) thus loaning its property and making the combination (blunt). No carrier is used during (driving) making the (pile) (sharp). First, a sharp pile is driven that is capable of accepting a blunt support.



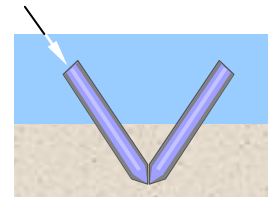
Separation in Time--Segmentation

Segmentation is (allowed and accomplished by an explosive charge). During (driving) several (individual) (piles) have the property of being (sharp) while unified or interacting through (a mechanical field). During (supporting) the unifying interaction is absent making them (blunt).



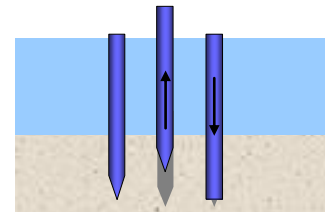
Separation in Time—Merging—Countering

Elements are configured, oriented or designed to oppose each other by (orienting them to oppose each other). Separating the (piles) during (driving) makes them (sharp). During (supporting) the merged (piles) oppose each other making them (blunt).



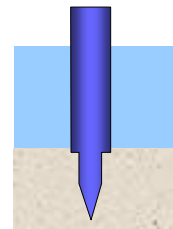
Separation in Time—Rearranging—Two Objects

Following driving, the sharp pile which is specifically designed for driving is extracted and the blunt one is driven into the resulting hole. Additionally, the sharp pile can have other features for driving such as strength, low mass and high stiffness which make the pile driving more rapid.



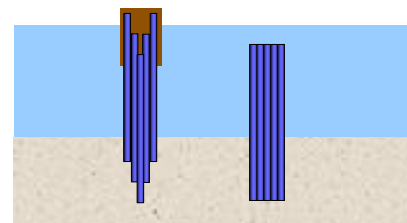
Separation in Time—Rearranging—Reorienting Non-Uniform

Part of a single (pile) is (sharp) while another part is (blunt). During (driving) the non-uniform (pile) is oriented so that (sharp) is emphasized. During (supporting) the (pile) is reoriented so that (blunt) is emphasized. By driving the pile, the blunt part comes into play at the right time to ensure that the pile can provide sufficient lateral support.



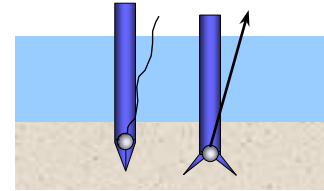
Separation in Time—Rearranging—Rearranging & Unfolding Parts

(Segmented Piles) are coordinated together. During (driving) the pieces are oriented so that they are collectively (sharp). During (supporting) the pieces are oriented so that they are collectively (blunt). The pile is made of multiple nested tubes which are shaped into a SHARP point by a cap which sits on top. Later, the cap is removed and the outer layers are driven until they are flush with the point, thus becoming BLUNT.



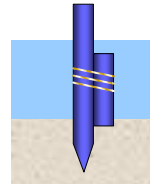
Separation in Time—Rearranging—Rearranging & Unfolding Parts

(Segmented Piles) are coordinated together. During (driving) the pieces are oriented so that they are collectively (sharp). During (supporting) the pieces are oriented so that they are collectively (blunt). The pile has parts that can be arranged to make it either sharp or blunt. A mechanism controls the shape. When the pile is being driven, it is SHARP. When the pile reaches a certain depth, the mechanism is released and the pile becomes BLUNT with further driving.



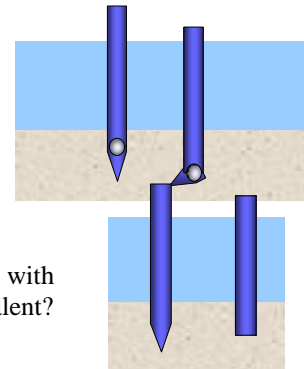
Separation in Time—Rearranging—Reorienting Attachments

Two (piles) which are (sharp) and (blunt) are attached to each other. During (driving) the pieces are oriented so that (sharp) comes into play. During (supporting) the pieces are oriented so that (blunt) comes into play. This is a true reorientation because the blunt part does not touch the soil in the beginning. The act of driving brings the blunt surface into play.



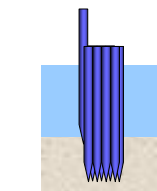
Separation in Time—Rearranging—Changing Direction

Changing directions of (the pile point) allows the setting to be changed. During (driving) the (pile point) is oriented so that (sharp) comes into play. During (supporting) the (pile point) changes direction so that (blunt) comes into play.



Separate Gradually—Test for Separate Gradually

Will a complete resolution of the contradiction allow starting with (sharp) (piles) and ending with (blunt) (piles) or their equivalent? This would be allowable so we will try to separate gradually.

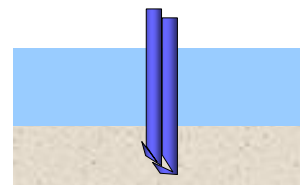


Separate Gradually—Gradually Merged

Multiple or segmented (piles) are available. Gradually merging the (thin) (piles) during (driving) results in the equivalent of (thick) (piles).

Separate Gradually—Merging—Merged Interaction

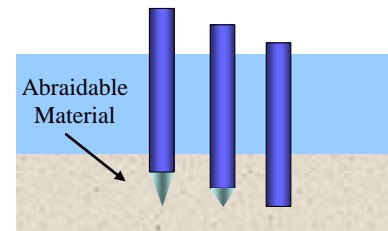
Multiple or segmented (piles) are available. Each (sharp) (pile) that is merged during (driving) with the already merged (piles) become (blunt) by (pushing down on a ledge protruding with a lip).



TRIZ Power Tools

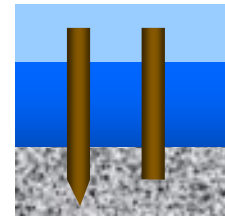
Separate Gradually—Gradually Transformed

The (pile) (tip) is made from (abraidable material). During (driving) the (pile) transforms from (sharp) to (blunt).



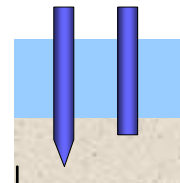
Separation in Space—Test for Separation in Space

During (supporting) (bluntness) is essential (where a supporting structure exists to keep it from falling over). (Sharpness) is essential where (nowhere) exists. These conditions do not overlap in space. However, since sharpness is essential nowhere we need to determine where it is allowable. It is allowable anywhere the vertical support is sufficient to carry the vertical load that the sharp pile cannot carry. The sharp pile is mostly carrying the lateral loads.



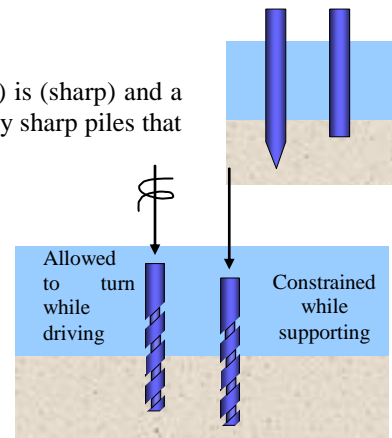
Separation in Space—Two Objects

If more than one type of (pile) is allowed, one (pile) is (sharp) and a nearby (pile) is (blunt). The structure is supported by sharp piles that carry the lateral load and blunt piles that support the vertical loads.



Separation in Space—Path

On a path (rotating along the axis of the pile) the (frontal area) is (small). On a path (linearly along the axis) the (frontal area) is (large). This is somewhat of a whimsical means of making a pile blunt and not blunt. If the pile is formed into a screw-like shape and the end is sharply formed, then it will twist as it goes in. Along this path, the pile frontal area is SMALL. However, when it is constrained and not allowed to turn then all of the material between the spirals makes the pile frontal area LARGE. The pile would require a very coarse pitch to allow it to be pounded in.



Test for Separation between the Parts and the Whole

Test for Separation between the Parts and the Whole:

Step 1: At a critical moment in time, should either (blunt) or (sharp) be hidden or minimized to solve the problem? No, there is no critical time in which both settings should be hidden or minimized.

Step 2: At a critical moment in time, do I want (sharp) and (blunt) to be expressed at different scales? No, there is no time in which we would desire both bluntness and sharpness.

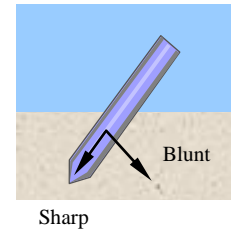
Step 3: If the answer to 1 and 2 is “no”, go to separation by direction. Otherwise, separate between the parts and the whole. Since the answer to both is “no” we would go to separation by direction.

Test for Separation by Direction

Does one of the conflicting properties already exist in a different direction or can it be modified to be so? The pile is already blunt in its sides. We conclude to try to separate by direction.

Separate by Direction

The (pile) is (sharp) (in the direction of driving). The (pile) (is already) (blunt) (at right angles) if (the supporting force is directed in the sideward direction). A pile is naturally blunt in all directions but the driving direction which is SHARP. If the pile is driven at an angle, it immediately creates a dull surface for vertical support. If several are joined crosswise, the net effect is a very BLUNT support after driving.



Test for Separation by Perspective

Is it sufficient too only appear to have one of the knob settings? No, it is not good enough. We need both properties to actually exist in the piles. We will go on to Separation by Perspective

Separation by Frame of Reference

The author could find no way to separate by frame of reference.

Separation by Response of Fields

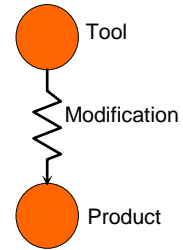
The author could find no way to separate by response of fields.

Separation between the substance and the fields

The author could find no way to separate between the substance and the fields.

L1-Solve by Neutralizing Harmful Functions

If the function that you are trying to idealize is a harmful function, then begin here. It may sound somewhat counterintuitive to consider idealizing something that is actually harmful. It would seem to instantly create an oxymoron. For instance, we might find ourselves considering the “ideal pain”, “ideal wear” or “ideal product failure”. While this might sound ridiculous, we shall see that there are ways to think about this that can turn harm on its head. In the end, harm must not exist and might even become useful. The book TRIZ Power Tools—Skill #5 Idealizing and Neutralizing Harmful Functions will describe the approach. When idealizing harmful functions, it is generally more important to prevent than to fix a problem.

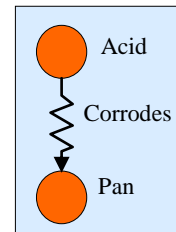


L2-Method

Go to the book TRIZ Power Tools—Skill #5 Idealizing and Neutralizing Harmful Functions and follow the approach.

Example—Acid Container

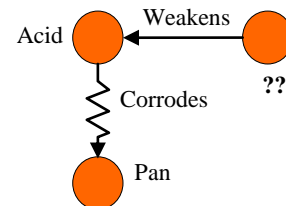
Recall that we had two harmful functions to idealize. The first was the acid corroding the pan. The second one comes from the affect of the earth pulling on the acid in the absence of a pan. Note that the approach that we used in idealizing useful function of positioning the acid allowed us to completely bypass the problem of the acid corroding the pan. Let’s pretend that we have not solved this problem and we are still looking for a way to not corrode the pan.



Go to the book TRIZ Power Tools—Skill #5 Idealizing and Neutralizing Harmful Functions and follow the approach.

Weaken or Misinform the Harmful Tool

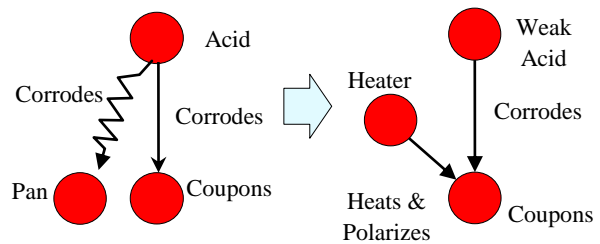
Ultimately what we want is for fewer hydrogen ions to attack the pan. This is not good because we need a strong acid to corrode the coupons. One way around this is next attack the contradiction. The acid needs to be weak in order to not corrode the pan and it must be strong on order to corrode the coupons. We can look at this possible contradiction later. There are different ways to do this such as diluting the acid or causing the hydrogen ions to react with a base to remove them from solution. Water can dilute the acid or any base can remove hydrogen ions. If we consider the tool performing it on itself, we realize that the negative ion which is also in solution with the hydrogen ions is capable of tying up the hydrogen



ions so long as water is removed from the solution. This brings us to the possibility of using the solid form of the acid which will not react with the pan.

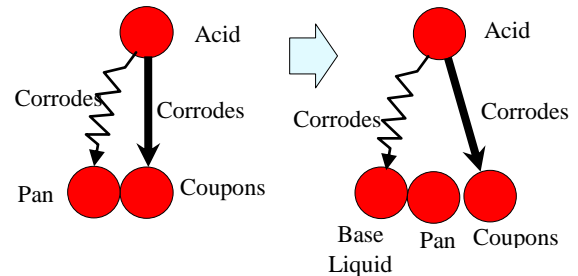
Max and Min Action with Minimum Field

We need to weaken the acid everywhere but at the location of corrosion. Harm does occur elsewhere, so we want the minimum corrosion field to occur everywhere except the location of the useful corrosion. Perhaps by manipulating the voltage of the coupons, we can use a weak acid and make it highly active at the place where we want it to corrode the most. It might also be possible to heat the coupons and cool the pan. This is interesting because the large oven might be no longer required. We can heat the coupons in a variety of ways such as attaching small resistance heaters. Directly running current through the coupons is also possible. This would also have the added benefit of activating the acid more highly where the cubes are and lowering the activity on the pan.



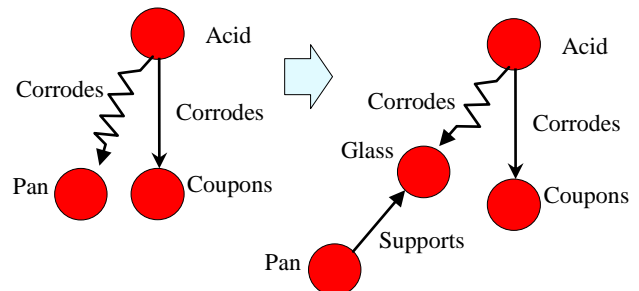
Max and Min Action with Maximum Field

We need to introduce a substance to draw off the corrosive action of the acid on the pan. We would like the corrosive action of the acid to be as high as possible on the coupons. The idea here is to draw off the harmful fields so that they go somewhere else. This means that the harmful molecular interaction that pull off the metal must pull off something else. If we go to a microscopic level, the molecules are packed tightly together, both in the liquid and in the metal. This means that the tendency to pull apart one molecule is drawn off by one that is very close by and the molecule that is pulled off is rapidly replaced by another. It is like either the molecules push between the metal molecules and present themselves as a sacrifice. Perhaps if the metal were porous, then a sacrificial fluid with high Ph (base) could fill the pores and be replenished. While this is not happening at a molecular level, it might be made to work.



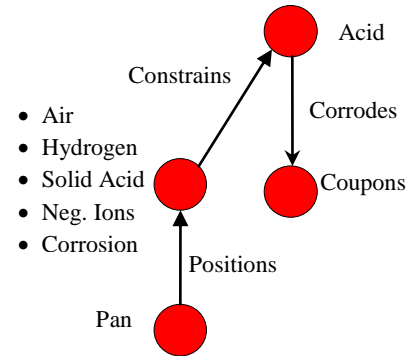
Mediator

Something must go between the acid and the pan. It is assumed that the pan material is the best possible to contain the corrosion in the first place. So, any substance used would have to be a sacrificial material. If we are going to use a



mediator then it must be one that is expendable but lasts long enough to do some good. Example of this would be inexpensive solid liners such as plastics or glass. It must still corrode slowly enough that it does not destroy the effectiveness of the acid.

Other acceptable mediators would be liquids or gases that can be replenished. They should be as inexpensive or free as possible. One good candidate is air that could be pumped in or made to fasten itself to the surface of the pan. Another interesting possibility is to use the hydrogen that is formed by the corrosion of the pan to protect the pan. In order for this to work, the hydrogen would need to coat the surface and then stay in place in such a way that the acid could no longer touch the wall.



The most acceptable mediator is one that is made of one of the materials of the interaction. Either it should be made from some form of the tool or the product. In our case, it may be best to form the mediator out of the solid form of the acid since it is unharmed by the liquid acid. We might find a way to form the solid acid to make this happen.

Another possibility is to use the negative ions in the fluid to protect the pan. The fields would need to be sufficiently strong to attract these negative ions.

One last possibility is to consider other types of corrosion. One in particular is quite interesting. It turns out that one reason that Tantalum is such a good material for corrosion is that a tantalum oxide (corrosion products not related to acid corrosion) is a very stable and protective material.

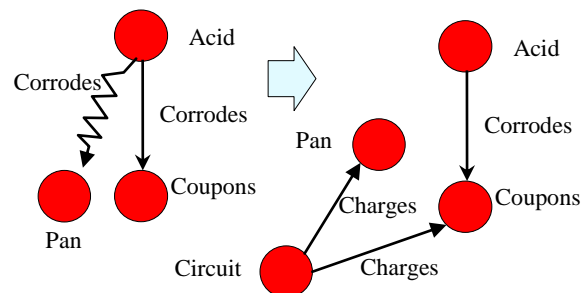
Redirect Harm to a Pre-weakened Expendable Product

It is possible to control the potential fields by introducing a sacrificial anode material that may be less expensive. This is similar to reversing the field on the pan to stop corrosion. Consult the following link:

http://www.efunda.com/materials/corrosion/stopping_corrosion.cfm

In order for this to work, the pre-weakened material would need to be right next to the pan material. The molecules would want to attack it first and because it goes away, it would need to be replenished very rapidly. One of the problems with this method is that the acid is rapidly degraded so that it is not as strong as necessary to attack the coupons. Therefore, the material must rapidly go back to its former condition. This suggests a chemical reaction that is equilibrium at all times, but is much more active at a molecular level than the reaction between the acid and the container.

Better yet, what if we could get the acid to preferentially attack the cubes? That is its primary function of the acid in the testing system. Perhaps we can make the coupons, themselves, into a prep-weakened structure that will take all of the harm. This is similar to using a sacrificial



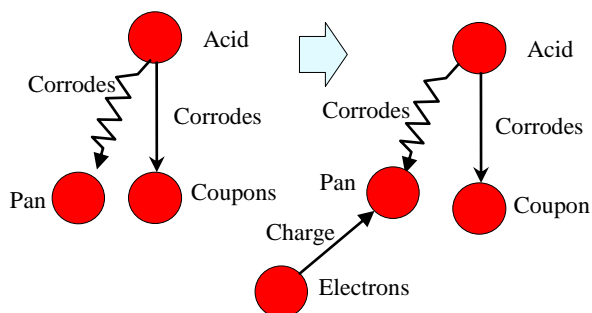
material in boilers to keep critical components from corroding. If the coupon, itself, becomes the sacrificial material, then the primary function of the system can only be improved. Corroding the coupons and sacrificing the coupons are essentially the same function. In boilers, the sacrificial material is chosen to create the correct electrochemical potential to keep the critical components from corroding. Since we may not know the sacrificial materials in advance, we can ensure that the coupon becomes the sacrificial material by creating a voltage differential between the pan and the coupons.

Redirect Extreme Action

This is not a case where the acid performs a useful action on the pan but a harmful action also occurs. This does not apply.

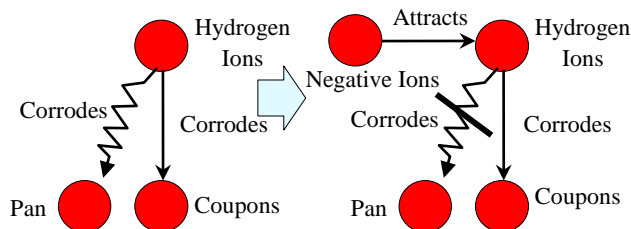
Counter Field

We would like to introduce a field into the pan to counter the fields that are dismantling the pan, molecule by molecule. Since the molecules of pan are pulled from the surface by electrostatic forces, we need to neutralize these forces. The fields in this case are the chemical fields which cause the corrosion. As we have before hinted, it may be possible to introduce fields sufficiently strong to neutralize the chemical fields. It may also be possible to make the pan from an appropriate material with a high enough potential to perform the action itself.



Channel Harm

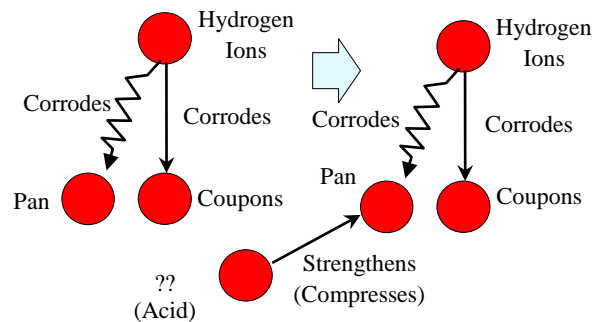
Electrostatic fields are pulling molecules from the surface of the metal. We want to channel these electrostatic fields away from the metal. These electrostatic fields are caused by the polar nature of the water and the Hydrogen ions. We need to identify a path of least resistance. The electrostatic fields of the positively charged ions would need to be channeled away from the metal at the atomic scale. One way to do this would be to force the negative chlorine ions into closer proximity with the H_3O^+ ions. The whole effect would make the positively ions much less mobile. This might be possible if the water molecules were greatly reduced. This brings up a new question. What happens when an acid has less and less water? As the water content decreases there are different species of ions formed with the water molecules. For instance, the crystalline form of form of $HCl \cdot H_2O$ (68% HCl), $HCl \cdot 2H_2O$ (51% HCl), $HCl \cdot 3H_2O$ (41% HCl), $HCl \cdot 6H_2O$ (25% HCl).¹⁴



¹⁴ http://en.wikipedia.org/wiki/Hydrochloric_acid

Strengthen the Product

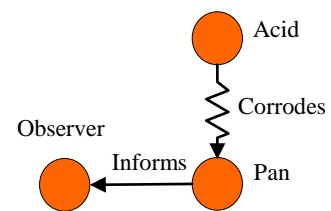
The pan must be strengthened while the hydrogen ions are trying to dismantle it. I believe that the property of the product that controls the harm is the strength of the bonds between the metallic atoms. We want these bonds to be as strong as they can be. It seems like it would be very difficult to increase the strength of the bonds between the atoms until we realize that corrosion on a surface is rarely uniform. This could mean that some regions have weaker bonds. When we look at metals through a microscope, we discover a grain structure which helps us to understand that the bonds between all atoms of a metal are not equal. This may especially be true of alloys. Stress corrosion, for instance, is the corrosion that occurs along the grain boundaries of certain metals when they are placed under stress. Could it be that the bonds which keep the material intact are weakened by stress and this makes them more susceptible to corrosion? This brings to mind the possibility that very high hydrostatic forces might hold the pan materials



together. Is it possible that the acid, itself could force the pan molecules together by the act of a high pressure on the metallic surface? At a molecular level, this looks like molecules striking the surface in rapid succession. It should be noted that when the function diagram was first drawn, the work strengthen was used instead of compresses. Nothing was shown for the tool that accomplished this function. If possible, the pan (product) should perform the function on itself to avoid adding any new elements to the system. This leads to an interesting contradiction. The acid molecules must be at an extremely high pressure to strengthen the pan molecules during corrosion and the acid molecules must be at low pressure to allow corrosion on the coupons that are being tested.

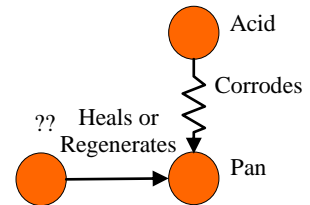
Detection of Harm

If the action of corrosion is difficult to control, then it may be necessary to detect it. However, for many of the methods that we have considered there will probably not be a requirement to detect corrosion. On the other hand, if an acid leak can occur, it may be necessary to detect it. For several of the approaches that we have considered, detection of harm would be helpful to make sure that further harm does not occur if acid begins leaking. The next step is to idealize the informing function so that an observer can detect the effect of the acid on the pan. First, we would look at the possibility of not requiring the detection. Then we would try to understand the ideal act of informing the observer and what that entails. Next, we would look for a physical phenomenon or scientific effect that could be used to inform the observer.



Healing or Regeneration

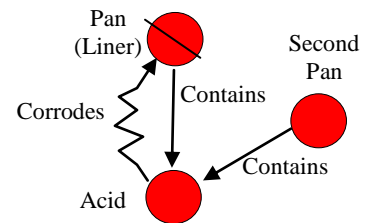
If we allow the corrosion of the pan to take place and are not able to find ways to avoid or stop the corrosion, then we would need to consider ways to remediate this harm. Healing means that, although the pan suffers corrosion, following a period of therapy, the affected areas go back to a state of not being pitted or weakened. Regeneration means that either new material grows into the spot that was corroded or a whole new pan is generated to take the place of the harmed pan. Healing the harm would mean that we are to replenish the dissolved material during corrosion or after corrosion. We note that the dissolved material is readily available as ions in solution, if we can just get it to go back onto the material. At this point, we would normally go to TRIZ Power Tools—Idealizing Useful Functions to look for ways to put the corroded material back where it belongs. Going back on to the material sounds like plating. It may be possible to make it go back, but it is difficult to get plating to go back into surface pits. The plated material wants to form on sharp edges where the electrical fields are high.



Previously Placed Cushion

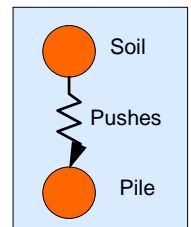
With a previously placed cushion, we are assuming that the harmful action occurs and that something else can take over for the failed product. In this case, we assume that the acid has corroded the pan and the pan is no longer useful.

What if the pan is no longer able to contain the acid? The second pan can take over for the first pan. The minimum is a very thin liner that can first be breached. Once breached, a second container which is very thick takes over. After each use, the first container is inspected and disposed of if no longer useful.



Example—Pile Driving

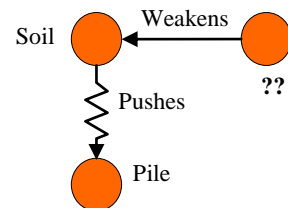
Reducing the resistance force decreases the requirement to get the most energy to the tip. If the soil does not resist the pile then the penetration is very easy and the problem is directly solved. Since this function is on the “strong path” and because all harmful functions on the harmful path are worth trying, we will consider idealizing or neutralizing this harmful function.



Go to the book *TRIZ Power Tools—Skill #5 Idealizing and Neutralizing Harmful Functions* and follow the approach.

Weaken or Misinform the Harmful Tool

The intention of this is to weaken the soil so that it does not push back on the pile. Since there are no intelligent agents here, we will not consider misinforming the soil. Weakening the harmful tool means that the soil cannot sustain a large amount of stress without moving out of the way. We must do something to make the yield stress of the soil as small as possible. One thing that comes to mind is to separate the soil particles. Other possibilities are to segment the soil further. Large rocks should become

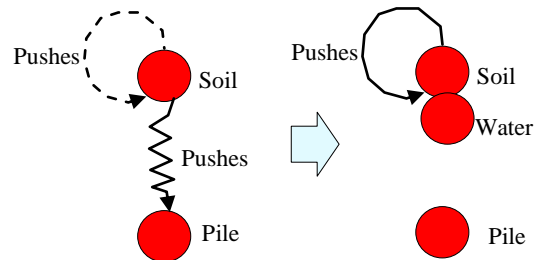


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sand. The shape of the soil particles should weaken the interaction between them. For instance, the shape of the soil should be round and small like little balls so that the pile glides easily through it. A lubricant could be used to decrease the interaction. One possibility is to have the water separate the soil particles to weaken their interaction. Since we are driving the piles in the water, it may be possible to also drive water between the particles of soil.

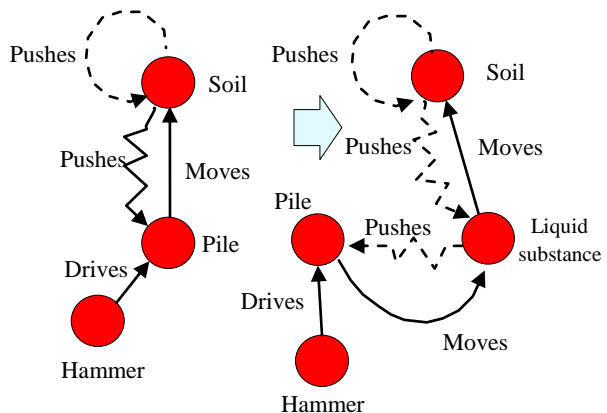
Max and Min Action with Minimum Field

We have a useful action of the soil pushing on itself. If we amplify the action of pushing on the soil everywhere, is there somewhere it is harmful? Yes, it is harmful on the pile tip. This is sufficient to invoke this approach. However, in order for it to work, the pushing field must be weak at the pile tip and then be strong everywhere else to push the soil. The field is minimal if we make it minimal. It can then be amplified to move the soil. The pushing of the soil on the pile must be weak, but where the soil pushes on itself, it should be amplified. This brings to mind the possibility of high forces generated in a thin layer of soil along the length of the pile which has high stresses, but at the pile tip, the forces on the pile are low. This may be possible if water is injected into the tip area where a small cross section is exposed to the water. The high forces on this small area generate high hydraulic pressures which could push up on the thin layer of water around the pile. The diagram illustrates that the combination of the soil and the water amplify the effect of pushing.



Max and Min Action with Maximum Field

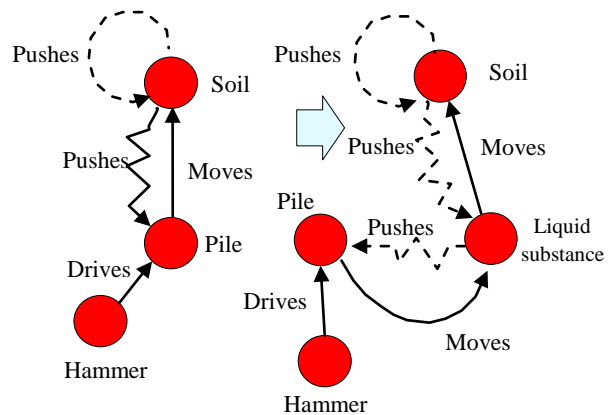
We need to introduce a substance to draw off the soil forces so that they do not push on the pile. We would like the field to be high in order to push the soil aside. The field location is distributed throughout the soil and is difficult to control. Channeling the harm away means that the pushing force of the soil on the tip of the pile goes somewhere other than the pile. Where can it go? The forces on the tip of the pile that move the soil have an equal and opposite force on the pile. This is probably not a good approach for counteracting this harmful function since a lot of soil needs to be moved. One way to



approximate this approach is to pre-insert a liquid substance into the soil. The new substance provides very little resisting force to the pile as shown in the diagram to the right. This is effectively a mediator, as will be shown in the mediator section, which must do the heavy moving of the soil itself. While the driving of the pile is faster, there is no guarantee at this point that the insertion of the liquid into the soil will speed the overall insertion time of the pile. Somehow you have to get the liquid into the soil. While we could take this further, we will not at this point.

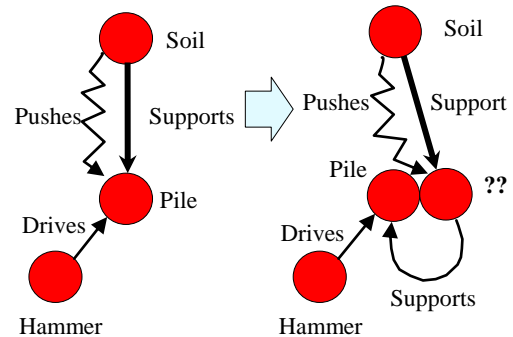
Mediator

A mediator is sought to put between the pile and the soil such that the pushing on the pile is diminished. Many materials could be used to enclose the pile. Unfortunately, anything that pushes on the mediator will also push on the pile. Placing a mediator between the pile and the soil does not diminish the reaction forces on the pile.



Redirect Extreme Action

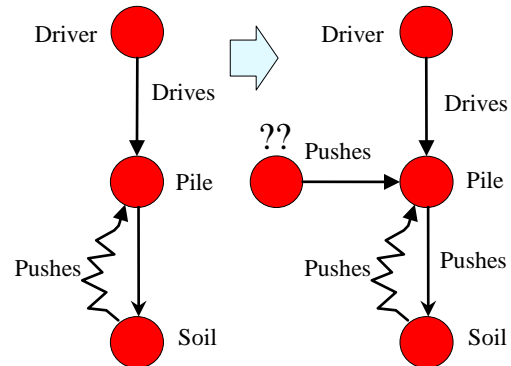
We are looking to see if this is a case where the soil performs a useful action on the pile and a harmful action is initiated or caused. The soil performs a useful action on the pile. It supports or pushes on the pile in order to support it. Unfortunately the action is not allowed for the driving. This means that we need to look for a way that the soil's useful AND harmful action of pushing should be directed toward a second object which is attached to the pile. The second object will then perform the function of supporting the pile. Notionally, the figure at the right shows us what we are attempting to do. The problem now becomes one of finding an object that does not push back on the pile while it is being driven, yet is capable of supporting the pile after the driving. It appears that this involves a contradiction. The laws of action and reaction would require that the supporting forces on this mystery object be transferred to the pile during driving. This implies that the pushing forces on the soil are very low during driving and the supporting forces are very high during supporting. For instance, this would be possible if the pile were driven into a liquid substance like concrete during driving and then later, the concrete would set to perform the supporting of the pile. Now a new problem is presented, how the concrete is present in the soil, or how the soil is turned into concrete.



Counter Field

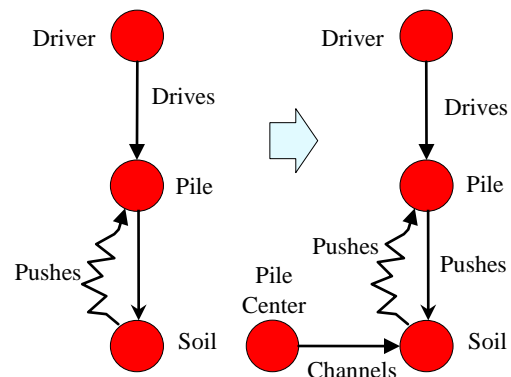
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Applying a counter field to the pile driver means that we need to look for a way to push back on the soil in a way that counters the force of the soil pushing back on the pile. The harmful field is a stress field. The soil pushes directly back on the pile. The second field should also be a stress field that pushes back with equal or greater field on the soil. The driver is the natural element to take on the additional function. This means that the driver drives harder. Note that the soil pushes back harder when the pile is driven harder. The pile drives faster, to be sure but the size of the pile driver needs to be increased. Also, there may be more damage to the part of the pile which is struck by the driver mass. These problems might be solved by idealizing harmful functions or by resolving the contradiction: the driver momentum must be high to drive faster and the driver momentum must be low in order to not break the pile.



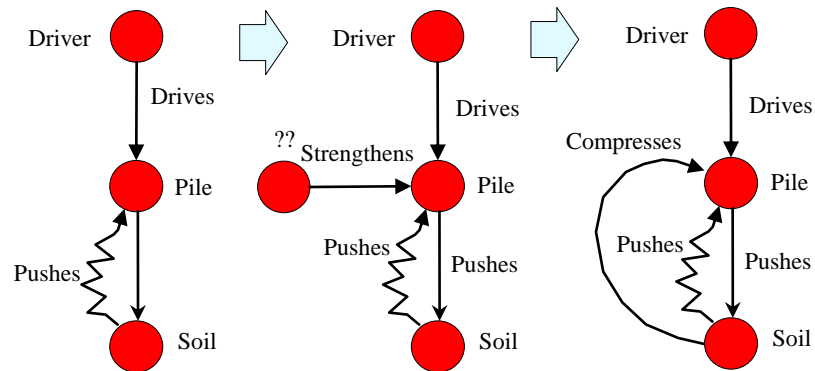
Channel Harm

We need to look for a way to channel the stress fields on the pile which push back when the pile is driven. The fields pushing back on the pile are stress fields. Channeling the harm away means that the pushing force of the soil goes somewhere, other than the pile. This can also mean that the soil, itself, moves somewhere other than away from the pile. The soil, itself, has another path. But there is no channel. Now we have a contradiction: a channel must be available in order to not push back on the pile, and a channel must not be available because there is no place to go. Another reason that a channel must not exist is that the final support of the pile is made worse if the soil continues to be channeled away while the pile is supporting a structure. One way to resolve this contradiction is to make the pile hollow. The soil has a place to go. We separate this in time and cap the channel to remove the channel and effectively provide a very blunt pile.



Strengthen the Product

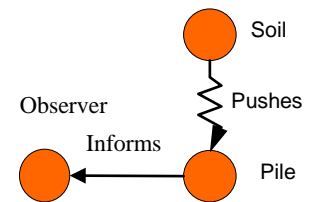
We want to strengthen the pile against the harmful action of the soil pushing back on the pile. One property of the pile that controls the harm of pushing is the area of the pile that is being pushed on. The function that would need to operate during driving would be one which reduces the surface area of the pile. This creates an interesting driving problem because we would need to identify a scientific effect or physical phenomenon which can reduce the area over which the pressure acts. One physical phenomenon is pressure acting on



the pile which would squeeze it into a smaller shape. Pressure is already provided by the soil, but the pile surface area is not very responsive to this pressure. In other words, it does change shape very much. It seems like the pile needs to have different properties in order to be compressed under the action of the soil. It would need to be made of an easily compressible material, and it should only be compressible in the radial direction so that it can drive into the soil. This leaves us with the contradiction when the pile gets smaller in diameter. The pile should be small in diameter in order to drive and it should be large in diameter in order to support the structure that will be built on it.

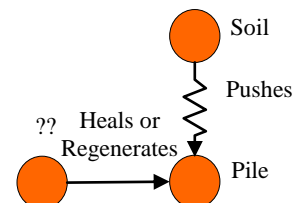
Detection of Harm

In this case, we are considering that it might be important for the pile to inform an observer that it is being pushed on. It seems a stretch that it would be important for the pile to inform an observer that pushing is taking place. Since there is an equal and opposite reaction of pushing the soil and pushing back on the pile, we know that if the pile is going down, then the soil is pushing back on it. Detection of the harm of pushing does not reduce any harm that might follow. On the other hand, detection of the useful function of driving the pile might have some value which we will not consider here. Since detection of pushing is not required, there is no further need to consider this step.



Healing or Regeneration

We would like to undo the effect of the soil pushing back on the pile. Healing or regenerating implies that we do this after the pushing has taken place. In this case, healing or fixing means that although the pile has been pushed back on by the soil, that some sort of action continues to drive the pile into the soil and makes up for the pushing action. Regeneration does not make sense in this situation. No way is found to "heal



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pushing” except to find some other means of pushing the pile further into the soil without the need for extra power from the pile driver, itself.

Previously Placed Cushion

In the case of the pile driver, something else should take over for the pile if it “fails”. The pile fails when it can no longer push the soil. Of course, it is not permanently disabled. Pile is no longer able to push the soil. This means that something else must push on the soil once the pile is incapable of pushing further. Perhaps water or the driver, itself, could be used to further push the soil. In the case of the driver taking over, it would need to be in direct contact with the soil. This creates a funny picture in the mind. We normally think of the driver as striking the pile. In this case, it directly strikes the soil and the driver. Perhaps, the most direct way to move the soil is to have the driver strike it directly and allow the pile to drop into the space that the driver clears. If water is involved, the water can be directly driven by the driver to move the soil. The pile is hollow. The driver extends through the pile and strikes the soil, or water, directly. The driver and water clear a sufficient path for the pile to drop into. Note that the final solution does not directly address the issue of a “failed” pile. Had we gone the normal route, we would likely have concluded that the pile does not actually fail permanently.

L1-Evolve the Leading Concepts

If you have used the full TRIZ format for developing your ideas, it is highly likely that you will have several viable concepts. Each concept will have its advantages over the others. The advantages are not inherent. It is common at this point to rank the ideas against each other. Since it is entirely possible to begin with a bad idea and turn it into a good idea, most productive approach is not ranking and eliminating. When people vote, there are so many hidden agendas that it is nearly impossible to determine what a good idea is.. It is usually more ideal to evolve the top concepts with the time that you have to reduce the risk as much as possible. In fact, one could continue to. It is still possible to improve each concept. This step also sets us up to combine the solutions.

Method

Step 1: identify the top concepts

Step 2: With the time available, evolve the top concepts until there are few risks.

Step 3: Ask what the main problems are.

Step 4: Loop back up to solving with existing solutions.

Step 5: Continue iterating back up to solving with existing solutions.

L1-Combine Solutions

Combining Concepts

Once we have refined the individual concepts, it is possible to create a highly enhanced product or process by the combination of the individual concepts. In order to do this, it is necessary evolve the individual concepts

If adequate resources are available, a DOE can be performed. DOE stands for Design of Experiment and is a favorite Six-Sigma tool for determining the relative strength of various knobs. In this context we are interested in the relative strength of each concept and how much of each idea should be combined into one final product. This can be practically done by a two level DOE where the concepts are combined in different combinations. This allows us to determine the combination of solutions that gives the most value to the customer or the business. The beauty of a DOE is that a partial list of combinations can be tried rather than the full compliment. The final output of the DOE is an equation that can be optimized to give the best “super product”. It is not the purpose of this text to go into detail on how to set-up or perform a DOE

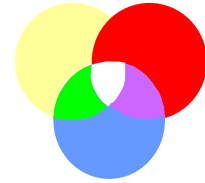
L1-Method

Step 1: Combine the top solutions in ways that make the combined solutions as simple as possible.

Step 2: Look for ways to consolidate the solutions.

L2-Combine Solutions

In many cases, only one good concept is required which satisfies all of the requirements. Other cases require the highest performance or reliability possible. If this is the case, a good tactic is to combine the solutions into a super-product which greatly extends the performance or reliability. This step sets us up to perform a Design of Experiment (DOE) as shown in the next step.



Method

Step 1: Consider different ways that they can be combined. Especially if the ideal solution is not created.

Step 2: Draw the combination possibilities

Step 3: Consider ways to simplify the combinations by consolidating component parts.

L2-Optimize the Combined Solutions

Continuing from the combine solution step, we need a strategy for combining the solutions. If there are many possible solutions, simply combining them all may not be wise. This is because there is often an “interaction” between the variables. The uninitiated will often suppose that simply combining solutions will give the best result. Actually, the combining of certain solutions may make the performance worse. This can be seen mathematically as an equation of combined variables such as $X1 \times X2$.

DOE

Up to now, screening tests should have been performed to determine rough cause and effect. These screening tests are performed by changing one variable at a time. In this step, we will purposely change several variables at a time. In order to save time, we will not consider all of the possibilities. This is the intent of the DOE, to consider a reduced subset of the total possibility of combinations. The reader should find a good source which explains how to design experiments.

Method

Step 1: Combine the concepts into two-level DOEs.

Step 2: Perform the tests. The output of the DOE will give sensitivities and interactions between knobs.

Step 3: Consider refinements to the final concepts based on the outcome.

L2-Document and Witness the Reduction to Practice

Whether you work for a company or are self employed, it is important the document the reduction to practice if the resulting concepts are patent worthy. Many concepts created by the methods in this book will be sufficiently non-obvious enough to patent.



Journal

Method

Step 1: Document the testing of the various combinations in your journal. The mathematical output of the DOE will support the reduction to practice.

Step 2: Sign and date the invention in the journal.

Step 3: Have two reliable witnesses sign and date an entry that indicates that they understand the combination of inventions and have witnessed the outcome of the DOE.

Step 4: As with all witnessing, use competent witnesses and have them sign and date the entries.

Appendix: Table of Fields

| | | | | | |
|---|------------------------------------|------------------------------------|-----------------|---------------|--------------|
| Elastic Force Internal & External | | Friction | Adhesive | | |
| Centrifugal Force | Inertia of Bodies (Note Direction) | Coriolis Force | | | |
| Buoyant | Hydrostatic | Jet Pressure | Surface Tension | | |
| Odor & Taste | Diffusion | Osmosis | Chemical Fields | | |
| Sound | Vibrations & Oscillations | Ultrasound | Waves | | |
| Corona Discharge | Current | Eddie Currents (internal and skin) | Particle Beams | | |
| Appendix: Table of Fields | Thermal Heating or Cooling | Thermal Shocks | Nuclear Forces | | |
| | Electrostatic Field | Magnetic Field | | | |
| | Electromagnetic (Voltage) | | Information | | |
| | Radio Waves | Micro-waves | Infrared | Visible Light | Ultra-violet |

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| | | GRANULITY OF INFORMATION | | | | | | | | | | |
|--|------|--------------------------|--------------------------------|----------------------------------|----------------------------------|---------------------------|-------------------------------|-----------------------------|---|-------------------------------|---------------------------------|---------------------------------------|
| | | ROUGH | | | | | FINE | | | | | |
| ASSOCIATE NOTICABLE DISTANCE OF INFORMATION SOURCE | WIDE | VISUAL | PRESENCE OF VISUAL INFORMATION | POSITION OF INFORMATION | SHAPE OF INFORMATION | | | | CONTENT OF VOICE/ TEMPORAL EVOLUTION | | | |
| | | | | | INTENSITY/ SIZE | BLINDING | | COLOR | FLASHING | SYMBOL/ LETTER | DIAGRAM/ SENTENCE | ANIMATION |
| | | AURAL | PRESENCE OF SOUND/VOICE | POSITION OF SOUND/VOICE | SHAPE OF INFORMATION | | | | CONTENT OF SOUND/VOICE TEMPORAL EVOLUTION | | | |
| | | | | | LOUDNESS OF SOUND/ VOICE | PAINFUL SOUND/ VOICE | | COLOR OF SOUND/ VOICE | VIBRATION | SIGNAL/ TONE MEANING | | MELODY /SONG/ SPEECH |
| | | THERMAL | NOTICE OF TEMPERATURE | POSITION OF TEMPERATURE | SHAPE OF TEMPERATURE | | | | PATTERN OF TEMPERATURE/ TEMPORAL EVOLUTION | | | |
| | | | | HOMO-GENOUS LOCAL | MAGNITUDE OF TEMPERATURE | PAINFUL | | | | TEMPERATURE GRADIENT | TEMPERATURE PATTERN ACROSS BODY | TEMPERATURE TEMPORAL EVOLUTION |
| CLOSE | | ELECTRICAL | PRESENCE OF ELECTRICAL CURRENT | POSITION OF ELECTRICAL CURRENT | SHAPE OF ELECTRICAL CURRENT | | | | PATTERN OF ELECTRICAL INTERACTION/ TEMPORAL EVOLUTION | | | |
| | | | | | MAGNITUDE OF CURRENT | GUIDING CURRENT | FORCING CURRENT | | AC/DC | | ELECTRICAL PATTERN ACROSS BODY | ELECTRICAL PATTERN TEMPORAL EVOLUTION |
| | | PHYSICAL | NOTICE OF SPECIFIC POSITION | POSITION OF PHYSICAL INTERACTION | SHAPE OF PRESSING/PULLING | | | | PATTERN OF PHYSICAL INTERACTION/ TEMPORAL EVOLUTION | | | |
| | | | | | MAGNITUDE OF PRESSING/ PULLING | GUIDING PRESSING/ PULLING | FORCING PRESSING/ PULLING | | VIBRATION | GRADIENT PHYSICAL INTERACTION | SHAPE OF PHYSICAL INTERACTION | PHYSICAL PATTERN EVOLUTION |
| | | CHEMICAL | NOTICE OF CHEMICAL DISBALANCE | POSITION OF CHEMICAL COMPOUND | SMELL/TASTE/DRUG SHAPE | | | | PATTERN OF CHEMICAL INTERACTION/ TEMPORAL EVOLUTION | | | |
| | | | | | MAGNITUDE OF SMELL /TASTE / DRUG | | SMELL /TASTE /DRUG DISCOMFORT | COLOR OF SMELL /TASTE /DRUG | | GRADIENT CHEMICAL INTERACTION | CHEMICAL PATTERN | CHEMICAL PATTERN EVOLUTION |

Table of Communication Fields¹⁵

¹⁵ Petr Krupansky February 2010