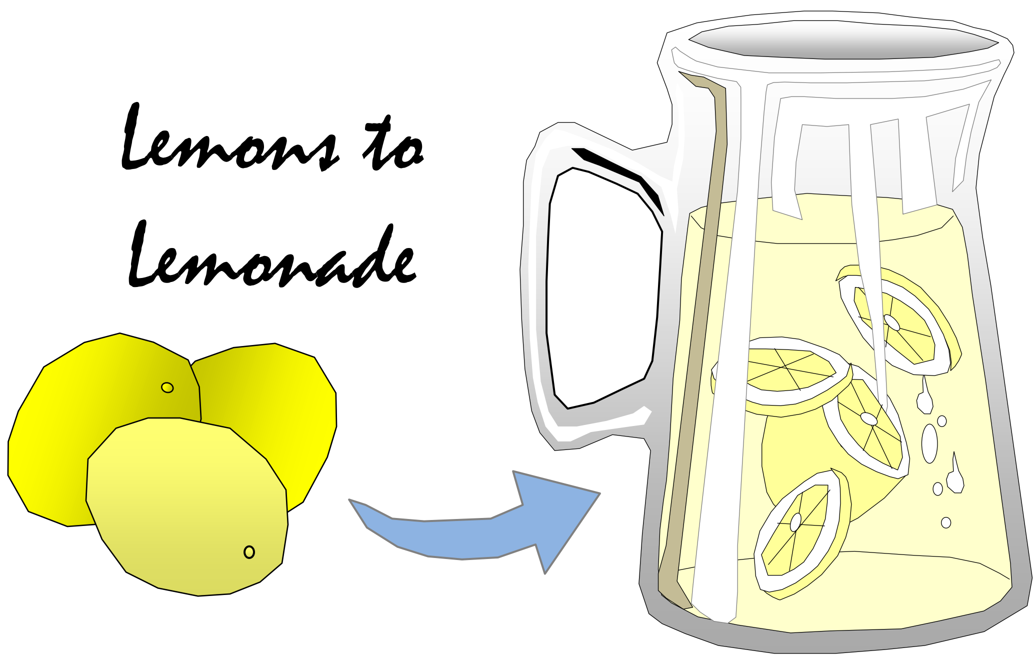
TRIZ POWER TOOLS

Skill #5 Idealizing Harmful Functions

May 2013 Edition



Avoiding Harm or Making it Useful

TRIZ Power Tools

Skill #5 Idealizing Harmful Functions

May 2013 Edition

ISBN Not yet applied for

TRIZ Power Tools by Collaborative Coauthors

51 Pages

Acknowledgements

This book is the work of a collaborative group of coauthors.

Coauthors

Larry Ball

David Troness

Kartik Ariyur

Jason Huang

Steve Hickman

Petr Krupansky

Larry Miller

Editors

Erika Hernandez

Larry Ball

David Troness

Paul Dwyer

S. Robert Lang

Illustrators

Larry Ball

David Troness

Other Authors, Theoreticians, Practitioners Whose Writings or Teachings have Impacted This Work

Genrich Altshuller

Ellen Domb

Roni Horowitz

John Terninko

Alla Zusman

Boris Zlotin

Lev Shulyak

Yuri Salamatov

Victor Fey

Eugene Rivin

Darrell Mann

Sergei Ikovenko

Simon Litvin

Peter Ulan

Lane Desborough

Clayton Christensen

Renee Mauborgne

Kim Chan

The Algorithm

(Table of Contents)

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 hierarchical; 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)

Each of the books in the TRIZ Power Tools book series are designed to be used as an algorithm. Each algorithm can be as detailed or simple as required. This is done by going up or down in the hierarchy of the process steps. The top level (L1) of the bookmarks is the highest level. If more detail is required, the user can go to deeper levels (L2 and L3). A "Cheat Sheet" may be separately provided at www.opensourcetriz.com which can be used to help the problem solver remember the details of the algorithm that are difficult to commit to memory.

Where the Book Materials Come From

Much of the material for this book was inspired by the thought leaders referenced. The original intent was to codify the insights of these thought leaders, but the exercise of codification ultimately led to the synthesis of other experimental processes. This is because codification required recognizing patterns of similarity of tools. Once this was achieved, the various tools were grouped with key decisions. Decisions require and create information which flows to the next decisions. Patterns and gaps became visible during this formative process. Experimental methods were inserted into the gaps. The proof of these experimental methods is whether they actually help the problem solver to identify product or process characteristics that will delight the market.

Idealizing Harmful Functions

One set of tools allow us to consider individual functions and ask: What do we ideally want our system to do? What are the ideal objects that our system should serve? Answers to these questions can change the nature of everything that follows. During this time of reasoning, we allow ourselves to question the very items that we thought our system was going to serve and how it would serve them. By this point, there is usually a lot that we are taking for granted about the job that the market is trying to perform. Although we are considering adding functions to the system, we do not yet know that these functions are required. For instance, the functions that we are considering might not be required if the system product or modification is not required. We may be able to find ways to satisfy the super-system (job) without performing these functions. In essence, we are questioning the original design decisions that brought the product or process into being the first time.

In the introduction to this series of books at www.opensourcetriz.com , 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 can use these approaches to focus in on one function at a time. When we create a 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.

The following steps are used to idealize or neutralize a harmful function:

Step 1: Identify an ideal tool. In this case, the ideal tool does not exist unless it has to.

Step 2: Identify an ideal modification. Since we are starting with a harmful function, we want the modification to be useful rather than harmful. This is more than just reducing the harm.

Step 3: Identify the ideal product. It ideal product cannot be harmed because it doesn't exist.

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 was a ready supply of approaches to describe the final state.

L1-Idealize Harmful Functions

Who would think that you could idealize something that is actually harmful? It doesn't make sense. We might find ourselves considering the "ideal pain", "ideal wear" or "ideal product failure". While this might sound absurd, we shall see that there are ways to think about this that can turn harm on its head.

How we handle harmful functions depends on what the tool or product does in the system. If the element is not required in the system at all (such as waste products) then it should be removed.

Objects which cause harm but also provide supporting functions can often be eliminated. Other objects in the system or super-system take over their function. If the object performs the primary function, it is usually more difficult to remove this element.

Whenever we have a case where the object must remain, then we must put it to work by making the harmful function useful. If this is not possible we may elect to weaken, channel or redirect the harm.

L1-Method

Step 1: Brainstorm the ideal tool: Find out why the harming parts are needed and then remove the need for these parts. Simply remove the harming part and then find something else to perform the useful function.

Step 2: Brainstorm the ideal modification: Look for ways to make the harmful function useful by reframing the harmful function in a useful context or by reversing the fields. Consider aesthetically incorporating the harmful effects or only performing them when useful. Consider storing the harmful effects for later use when they are useful.

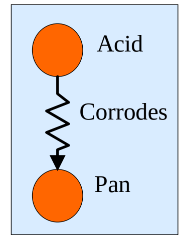
Step 3: Brainstorm the Ideal Product: If the product is a waste product, look for ways that it doesn't need to exist.

Example—Acid Container

In the TRIZ Power Tools book Resolving Problems, we introduced an example problem of acid corroding an expensive pan that is used to position the acid relative to the cubes. We looked at too causal approaches. The first was related to determining why the pan was required. The second approach required us to look at all aspects of the problem, including the question of why the pan was required. Note that in many problems, we don't need or even want to understand every aspect of what is causing the problem since often we can bypass the main problems by simply understanding why the problematic elements are required in the first place.

The first approach of understanding why the pan was required led us to idealizing the useful function of positioning the cube without a pan. In this case, we were able to completely bypass the problem of corroding the pan since the cubes or "coupons" became the pan. Had we taken this approach, we could have avoided the more time consuming approach of looking at many aspects of the problem that ultimately were irrelevant.

In the second causal approach, we chose to perform a full-up causal analysis. This analysis was more costly from a time point of view since it considered everything related to the problem, including why pan was required to position the acid. Aside from the fact that a full-up causal analysis probably wasn't required for this problem, it does illustrate what might have occurred had we not been able to use the bypass approach of understanding why burdensome or problematic elements are required in the system.



In using the full-up causal approach, we identifed the harmful function of the acid corroding the pan. For the purposes of illustrating idealizing or neutralizing harmful functions, we will consider this problem through the book.

Step 1: Brainstorm the ideal tool: Find out why the harming parts are needed and then remove the need for these parts. Simply remove the harming part and then find something else to perform the useful function.

In this context, I am asking myself why the harming acid is needed. The acid is required to corrode the metal cubes or coupons to test them. Since corroding the cubes is the primary function of the testing, then I don't want to remove the acid. This leaves me with the contradiction that the acid must and must not exist. We can take this up later.

The second part is to remove the harming part and then replace it with something that performs the required function. Again, the testing is performed to see how the material will respond to the specific acid. A substitute acid or other compound is not acceptable, the best that we can do is a contradiction. An acid is used in order to corrode the cube and something which is non-corrosive is used in order to not corrode the pan. Along with the first contradiction, we can take this up later.

Step 2: Brainstorm the ideal modification: Look for ways to make the harmful function become useful by reframing the harmful function in a useful context or by reversing the fields. Consider aesthetically incorporating the harmful effects or only performing them when useful. Consider storing the harmful effects for later use when they are useful.

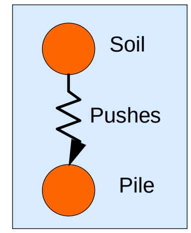
If we reframe the acid corroding the pan as a useful function, then we might say that the acid is shaping the pan. This is an interesting way to look at the problem. In order to usefully "shape" the pan, we would like the acid to corrode uniformly. This makes us realize that one of the main reasons that the pan is useless is because most corrosion is very non-uniform. If we make the corrosion uniform then the pan lasts a lot longer. We have transformed the question to "How can we make the corrosion on the pan very uniform?" Were we to continue this line of thinking we would be starting with a new system having a new problem, that of non-uniform corrosion. We would go back through the process of understanding why the pan corrosion is non-uniform. Note that this did not show up on the original causal analysis because we missed this parameter. For the purposes of this book, we will leave this line of reasoning here.

Step 3: Brainstorm the Ideal Product: If the product is a waste product, look for ways that it doesn't need to exist.

In this case, the pan is not a waste product, so we will not consider this further.

Example—Pile Driving

In the TRIZ Power Tools book Resolving Problems, we introduced an example problem related to reducing the time that it takes to drive a pile. We performed a full-up causal analysis and identified a harmful function on one of the strong paths: the soil pushes back on the pile as we attempt to drive it into the soil. 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 a "strong path" in the causal analysis, we will consider idealizing or neutralizing this harmful function.



Step 1: Brainstorm the ideal tool: Find out why the harming parts are needed and then remove the need for these parts. Simply remove the harming part and then find something else to perform the useful function.

The harmful tool is the soil. We need the soil in order to support the vertical and lateral loads on the pile. As the pile is driven deeper, the harmful forces of the soil pushing back become greater. This is because of the weight of the soil at the greater depth. Eventually, the forces become so great that it is difficult to drive the pile deeper. This is useful, later, when a structure is placed on top of the piles and an earthquake is trying to drive the pile deeper. Also, the deeper the pile is driven, the higher the lateral loads that can be supported.

First we try to remove the need for the soil. If the soil was very solid, like a rock, it would not be necessary to drive the pile into it. The pile could be attached to the surface of the rock and all of the vertical and lateral support necessary would be available. The structure of the piles above the surface of the rock would need to be changed to handle the lateral loads as the pile can no longer be a buried cantilever. If we chose this approach, sandy soils would need to become solid. This replaces the original problem with the question: how can the soil become solid enough to support a structure attached to its surface? Different approaches would be used to make the soil more solid.

The second approach is to remove the soil and replace it with something else. This would necessitate digging out the soil and replacing it with something more solid. The added effort of removing the soil and replacing it is time consuming. If we choose to go down this solution path then it is likely that the contradiction arises: how can the soil be replaced and not replaced.

Step 2: Brainstorm the ideal modification: Look for ways to make the harmful function become useful by reframing the harmful function in a useful context or by reversing the fields. Consider aesthetically incorporating the harmful effects or only performing them when useful. Consider storing the harmful effects for later use when they are useful.

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.

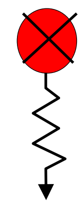
Effectively, the above approach is the same as reversing the fields. Aesthetic incorporation is not helpful here. We already perform the action of pushing back on the pile when it is useful when we apply static structures atop the pile. Storing the harmful effect does not seem to apply here.

Step 3: Brainstorm the Ideal Product: If the product is a waste product, look for ways that it doesn't need to exist.

The ideal product of a harmful function is a waste product. In this case, the pile is not a waste product and so this step does not apply here.

L2-The Ideal Tool

The Ideal Harmful Tool Does Not Exist



Elimination is one of the most commonly taught methods of dealing with harmful functions. If we are successful at eliminating an object, then the system is simplified and we come closer to the ideal final result. There are a number of reasons that a tool might not exist. For instance, it might not be required because it is considered waste in the system. The tool may perform an auxiliary function and therefore can be eliminated. By solving a problem in the system, the auxiliary function may not be required.

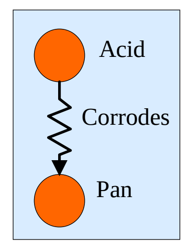
L2-Method

Step 1: Look for ways that the harming tool does not need to exist. Identify why the tool is required and change the system so that it is no longer required.

Step 2: Sometimes the tool is a waste product or is not required by the system in the first place. If this is the case, then find ways to remove the product, its path or its source.

Example—Acid Container

Whether or not the acid is useful, we are trying to find a way to make the acid go away.



Step 1: Look for ways that the harming tool does not need to exist. Identify why the tool is required and change the system so that it is no longer required.

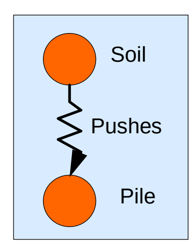
The acid is required to determine the effect of acid on coupon samples. The specific acids must exist. In this case, we assume that the acid must exist. This can lead us to the contradiction that the acid must exist in order to corrode the coupons and it must not exist in order to not corrode the pans.

Step 2: Sometimes the tool is a waste product or is not required by the system in the first place. If this is the case, then find ways to remove the product, its path or its source.

This does not apply here because the acid is not a waste product.

Example—Pile Driving

Regardless of how useful the soil is to supporting structures placed on the piles, we are going to consider ways that the soil will not exist.



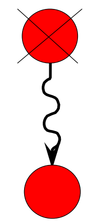
Step 1: Look for ways that the harming tool does not need to exist. Identify why the tool is required and change the system so that it is no longer required.

The soil is used to vertically and laterally support the piles. It is not needed if the structures placed thereon do not need the support. In this case, we need the soil. This can lead to the contradiction that the soil must exist in order to support the piles and it must not exist in order to not push against the pile while driving.

Step 2: Sometimes the tool is a waste product or is not required by the system in the first place. If this is the case, then find ways to remove the product, its path or its source.

The soil is not considered a waste product. This step does not apply.

L3-Tool Not Required



It is very common for a tool to cause both harmful and useful functions. Understand why the harmful tool is required in the first place. If a Causal Analysis Diagram is being used, it is easier to follow the chain of reasoning back to the problems that the function helps to resolve. Practically, this is done using a causal analysis diagram by considering the existence of a tool or product of a function as an object attribute that causes the problem. (Seeing the function in the cause effect diagram reminds us that existences of the elements of the function are object attributes that should be considered.) When we consider non-existence of elements in the system (in the side-by-side box), we begin an alternative problem path which leads us to understand why an element was originally required in the system. It is possible to remove the need for the troublesome element and often other elements by resolving a problem elsewhere in the system. This is done by tracing back the alternative problem path.

Non-existence of a function element is shown with a new function which has no tool. The tool was required to perform a function which no longer is performed because the tool is missing. One solution of the alternative problem path is to find a new way to perform the function of the missing object. This often leads to the consideration of how the function might be performed by existing elements, thus simplifying the system.

A slight change to an object in the system (often the object that we are serving) removes the requirement for the main function and hence the objects that deliver the function. In other words, if something did its job better then our system wouldn't be needed.

Method

Step 1: What is the useful function of the harmful tool and why is the Function Required? What does it prevent? What does it fix? What does it make up for? Does it counter something? Follow this reasoning back through the causal relationships.

Step 2: Resolve the problem that made the tool necessary in the first place. With the problem resolved, the function and all of its supporting functions are no longer required. These elements can then be removed from the system.

Example—Water Rinse

The residue from a water rinse makes subsequent metal plating less predictable. Sometimes, the plating falls off during heat treat.

Step 1: What is the useful function of the harmful tool and why is the Function Required? What does it prevent? What does it fix? What does it make up for? Does it counter something? Follow this reasoning back through the causal relationships.

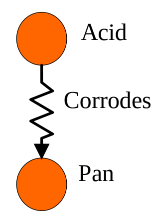
The water rinse is required to remove soap that is used to wash oil from the part. The oil is on the part to cool and lubricate the part during machining. It is also useful to reduce corrosion of the part following machining and during storage of the part.

Step 2: Resolve the problem that made the tool necessary in the first place. With the problem resolved, the function and all of its supporting functions are no longer required. These elements can then be removed from the system.

If the machined part is cooled during machining with something other than oil, or machined with a process that does not require lubricant; and if the part does not need storage following machining, the lubricant, soap and rinse are not required prior to plating. The system is greatly simplified.

Example—Acid Container

This is a more detailed example of determining why the acid must exist. Here we determine why it is required or if there is a way that it is not required.



Step 1: What is the useful function of the harmful tool and why is the Function Required? What does it prevent? What does it fix? What does it make up for? Does it counter something? Follow this reasoning back through the causal relationships.

The acid performs a primary useful function in the system of corroding the coupons. The acid does not prevent, fix, make up for or counter anything. If we could have found a remedial or preventive function that it performed, perhaps we could have removed it.

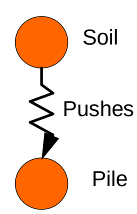
Step 2: Resolve the problem that made the tool necessary in the first place. With the problem resolved, the function and all of its supporting functions are no longer required. These elements can then be removed from the system.

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.

Example—Pile Driving

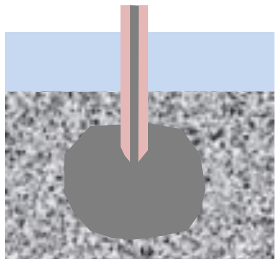
function.

Step 1: What is the useful function of the harmful tool and why is the Function Required? What does it prevent? What does it fix? What does it make up for? Does it counter something? Follow this reasoning back through the causal relationships.



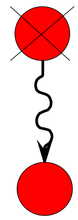
The useful function of the soil is to support the pile against vertical and lateral loads. The soil prevents water from eroding away the lower soil which supports the pile. It performs preventative functions of keeping the structure from moving under the lateral loads of water and earthquake loads. It performs the useful function of supporting the structure under an earthquake load. If the effects of the earthquake could be mitigated in other ways then the pile would not need to be driven so far. For instance, if the soil did not move under the pile in an earthquake, the soil would not need to be so deep. In effect, the soil needs to include a very large and stable structure upon which the piles rest.

Step 2: Resolve the problem that made the tool necessary in the first place. With the problem resolved, the function and all of its supporting functions are no longer required. These elements can then be removed from the system.



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.

L3-Non-Existent Tool



It is very common for a tool to cause both harmful and useful functions. Eliminating the tool will remove the harm, but now there may be a necessity to transfer the performance of the useful function to something else. It is most likely that the tool can be eliminated if it performs auxiliary functions or actually not required at all in the system. Note that it may be necessary to use some of the components of Idealizing Useful Functions to identify potential tools that can perform the useful function of the tool that was removed.

Method

Step 1: Simply eliminate the tool and identify something else in the system that can perform the function of the tool. It may be necessary to use Idealizing Useful Functions to identify a suitable tool. If it is difficult to remove then consider the following.

—Eliminate the source of the tool.

—Eliminate the movement or path of the tool

—Redirect the movement of the tool

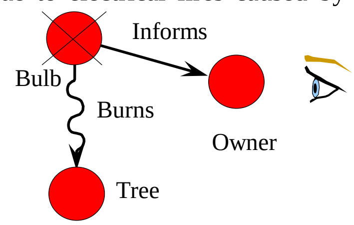
—Redirect the movement of the tool by creating another path of least resistance

—Absorb the Tool: Use Porous materials[1]—Fabrics—Batting—Gel

1 Inventive Principle #31—Porous Material: Make an object porous, or use supplementary porous elements (inserts, covers, etc.). If an object is already porous, fill poured in advance with some substance. Genrich Altshuller, The Innovation Algorithm page 289.

Example—Christmas Tree Fires

Many homes are burned each year during Christmas due to electrical fires caused by bulbs. The bulbs perform a harmful and a useful function



Step 1: Simply eliminate the tool and identify something else in the system that can perform the function of the tool. It may be necessary to use Idealizing Useful Functions to identify a suitable tool. If it is difficult to remove then consider the following.

—Eliminate the source of the tool.

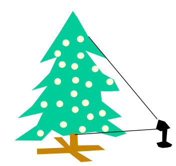
—Eliminate the movement or path of the tool

—Redirect the movement of the tool

—Redirect the movement of the tool by creating another path of least resistance

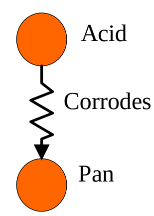
—Absorb the Tool: Use Porous materials[2]*—Fabrics—Batting—Gel*

The bulb is eliminated. Now we consider what will perform the function of the bulb. The ornaments could replace the bulbs and give off small points of light. We can use small luminescent stickers on the ornaments that glow when illuminated with a black light.



Example—Acid Container

Without regard for the useful function of the acid, we will remove it form the system.



Step 1: Simply eliminate the tool and identify something else in the system that can perform the function of the tool. It may be necessary to use Idealizing Useful Functions to identify a suitable tool. If it is difficult to remove then consider the following.

—Eliminate the source of the tool.

—Eliminate the movement or path of the tool

—Redirect the movement of the tool

—Redirect the movement of the tool by creating another path of least resistance

—Absorb the Tool: Use Porous materials[3]*—Fabrics—Batting—Gel*

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

---

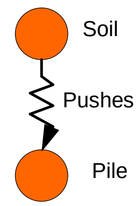
2 Inventive Principle #31—Porous Material: Make an object porous, or use supplementary porous elements (inserts, covers, etc.). If an object is already porous, fill poured in advance with some substance. Genrich Altshuller, The Innovation Algorithm page 289.

3 Inventive Principle #31—Porous Material: Make an object porous, or use supplementary porous elements (inserts, covers, etc.). If an object is already porous, fill poured in advance with some substance. Genrich Altshuller, The Innovation Algorithm page 289.

is allowed, we again end up with the contradiction: The acid must and must not exist in the system.

Example—Pile Driving

The soil provides the useful function of supporting the pile against vertical and lateral disturbance forces. If we remove the soil then something else must provide this useful function.



Step 1: Simply eliminate the tool and identify something else in the system that can perform the function of the tool. It may be necessary to use Idealizing Useful Functions to identify a suitable tool. If it is difficult to remove then consider the following.

—Eliminate the source of the tool.

—Eliminate the movement or path of the tool

—Redirect the movement of the tool

—Redirect the movement of the tool by creating another path of least resistance

—Absorb the Tool: Use Porous materials[4]—Fabrics—Batting—Gel

With the soil removed, we look around for something else to provide the support for the piles. Anything that replaces the soil will require time and additional equipment. No solution is found.

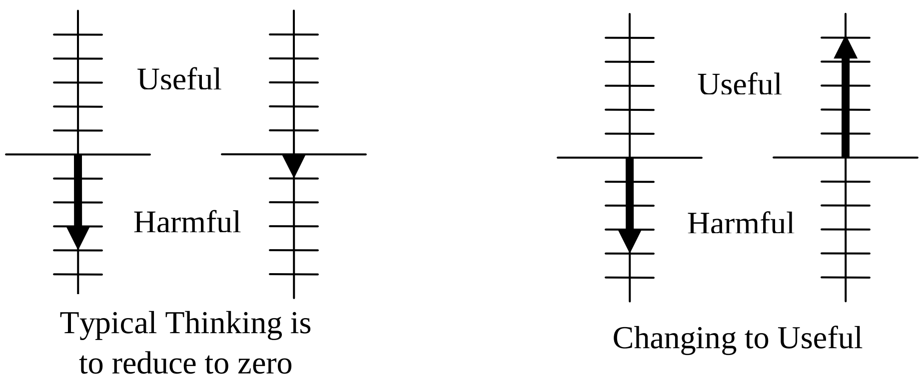
4 Inventive Principle #31—Porous Material: Make an object porous, or use supplementary porous elements (inserts, covers, etc.). If an object is already porous, fill poured in advance with some substance. Genrich Altshuller, The Innovation Algorithm page 289.

L2-The Ideal Modification (Make Useful)

The Ideal Harmful Modification is Useful

Our next attempt to idealize harmful functions is to change them into useful functions. This is truly making lemonade out of lemons, which is generally not the first thing that people think of. It is often easier to conceptualize the reduction of harm to zero. If one were to think of this on a sliding scale, the harmful function is large in magnitude.

The sliding scale decreases the harm until it reaches zero. What if we continue reducing the harm? The only way to do this is to make the function increasingly useful on the same product! An algorithm is given for making this seemingly impossible transition, from harmful to useful, possible.



The typical approach to reducing harm is to identify object attributes such as size, position, duration, color and then adjusting the level of these attributes. Here, we take an entirely different approach.

We actually want to do something that is truly valuable with that which was harmful. This creates the possibility of eliminating elements, especially if the new useful function performs a function done by something else in the system.

L2-Method

Step 1: Reframe the harmful function as a useful variant and then boost the newly created useful function. The useful function can be the anti-function. One method for performing the useful variant can be imagined using intelligent little people.

Step 2: Simply reverse the fields and ask if they now can perform a useful function. Sometimes it is easy to reverse the fields.

Step 3: Work with the function, strengthening it in a way that it becomes useful or aesthetically incorporating the harmful effects.

Step 4: Make the harmful function adjustable and ask whether this newly adjustable function can be useful. When it is adjustable perform it within the range or accurately enough to make it useful.

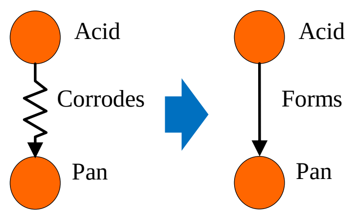
Step 5: Harmonize the sequence of functions so that when it is performed, it is useful. This can also be done by storing the harmful function or its effects to be used when it is useful.

Step 6: Combine the harmful function with other harmful functions to make it useful.

Example—Acid Container

Step 1: Reframe the harmful function as a useful variant and then boost the newly created useful function. The useful function can be the anti-function. One method for performing the useful variant can be imagined using intelligent little people.

The harmful action of "corrodes" is reframed to "forms". So instead of the acid corroding the pan, instead 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. 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 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. This additionally will decrease the kinematics of the molecules and consequently the corrosion rate of the pan.



Step 2: Simply reverse the fields and ask if they now can perform a useful function. Sometimes it is easy to reverse the fields.

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

This is one of the strongest solutions to date.

Step 3: Work with the function, strengthening it in a way that it becomes useful or aesthetically incorporating the harmful effects.

This does not apply as aesthetics are not important.

Step 4: Make the harmful function adjustable and ask whether this newly adjustable function can be useful. When it is adjustable perform it within the range or accurately enough to make it useful.

We have already considered a way to make it adjustable: adjust the voltage of the pan. In our case, this adjustability does not help us as we want to completely remove the harmful effects, we will adjust the voltage suitably to completely halt the corrosion.

Step 5: Harmonize the sequence of functions so that when it is performed, it is useful. This can also be done by storing the harmful function or its effects to be used when it is useful.

This implies that there might be a time that we want to corrode the pan. This might occur during cleaning which is done to keep the test acid as pure or controlled as possible.

Step 6: Combine the harmful function with other harmful functions to make it useful.

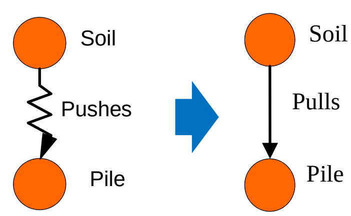
If it is necessary to clean the pan from time to time then corrosion might be used for this process. If we electrify the pan, then it might be possible to corrode or electro-polish the pan for a short period of time to remove unwanted materials from the surface.

Example—Pile Driving

The goal of this approach is to make the pushing of the soil on the pile useful. Since this is not the usual way that people think, we are likely to find new ways to overcome this harmful function.

Step 1: Reframe the harmful function as a useful variant and then boost the newly created useful function. The useful function can be the anti-function. One method for performing the useful variant can be imagined using intelligent little people.

We repeat the approach of level 1. 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.

Step 2: Simply reverse the fields and ask if they now can perform a useful function. Sometimes it is easy to reverse the fields.

Effectively, the above approach is the same as reversing the fields if you can get the friction forces to pull rather than push the pile. You have to get the friction forces pulling in the right direction..

Step 4: Make the harmful function adjustable and ask whether this newly adjustable function can be useful. When it is adjustable perform it within the range or accurately enough to make it useful.

This approach asks us to make the pushing (not pulling) action adjustable. The force of the soil against the tip must become adjustable. We can either adjust the soil or the pile. While it is possible to adjust the soil, as we have already seen, it is usually more difficult to adjust natural objects since there is usually a lot of variation related to natural objects. While one technique may work on some soils, it may not work on others.

There are a couple of parameters that could make the pushing action of the soil adjustable. One is the frontal area of the pile and the other is the tip angle. From experience, the tip angle has the least effect at greater depths. The main thing that changes the force is the frontal area of the pile. If the area of the pile is adjustable then the driving force becomes adjustable.

Now we ask, if the resisting force is adjustable, does the resisting force become useful? In this case, the answer is no, it does not become useful. It only becomes less harmful. It only becomes more useful if the force can be adjusted enough to become a pulling force.

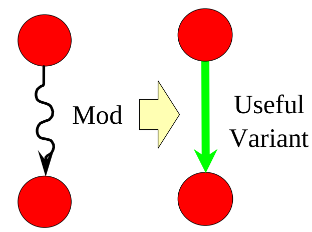
Step 5: Harmonize the sequence of functions so that when it is performed, it is useful. This can also be done by storing the harmful function or its effects to be used when it is useful.

There is no time during driving that the resisting force can become useful.

Step 6: Combine the harmful function with other harmful functions to make it useful.

None are found.

L3-Reframe as Useful Variant



This approach is an unusual but powerful way to turn lemons into lemonade[5]. What we are trying to do is to reframe a harmful action so that it is now useful. The now-useful function may be able to take over for other elements in the system. The system can often be reduced by pressing elements into performing more functions[6].

This approach is like a criminal trying to rationalize their crime in a way that everyone thinks that it was truly a good thing that he did. "I wasn't holding up the store, I was helping the store owner to test the store security". Virtually every harmful action has a useful variant or context.

For instance, if one part is wearing another part, we can ask ourselves "Where are the contexts where we want wear to happen?" We want to make this happen in situations where we are polishing or grinding on purpose. Going back to the criminal analogy, he would say "I wasn't wearing the surface; I was just trying to polish it!" If we reframe the harmful variation as a good one, then we can boost this function and make it truly useful.

Examples:
Melt —> Form
Wear —> Form
Break —> Disassemble
Tear —> Cut
Burn —> Cook
Disturb —> Control
Corrode —> Secure
Corrode —> Form

If we are having problems coming up with a useful variant, there are some ways to change our perspective. For instance, almost any harmful function can be made useful if it can be made adjustable[7]. Adjustable friction becomes traction control. Adjustable wear becomes forming. If a function can be made adjustable, sometimes it can perform a useful variant if it can be amplified sufficiently[8]. Also, we can remove ourselves from the situation and look for situations, not related to the problem where the harmful function is considered useful. Getting used to this method of thinking requires some practice or experience, but the change in perspective can be very satisfying.

Following this approach are several methods for helping us to see a useful variant in a harmful function. For instance, the anti-function can often be performed as a useful function.

Method

Step 1: Cast the harmful function on the product in a useful context with relation to the given product. If it is difficult to identify a situation then look for situations not related to

5 Inventive Principle #22—Convert Harm Into Benefit: Utilize harmful factors - especially environmental to obtain a positive effect. Remove one harmful factor by combining it with another harmful factor. Increase the degree of harmful action to such an extent that it ceases to be harmful. Genrich Altshuller, The Innovation Algorithm page 288.

6 Inventive Principle #6—Universality: an object can perform several different functions ; therefore, other elements can be removed. Genrich Altshuller, The Innovation Algorithm page 287.

7 Inventive Principle #15—Dynamicity: Characteristics of an object or outside environment, must be altered to provide optimal performance at each stage of an operation. If an object is immobile, make it mobile. Make it interchangeable. Divide an object into elements capable of changing their position relative to each other. Genrich Altshuller, The Innovation Algorithm page 288.

8 Inventive Principle #22—Convert Harm Into Benefit: Utilize harmful factors - especially environmental to obtain a positive effect. Remove one harmful factor by combining it with another harmful factor. Increase the degree of harmful action to such an extent that it ceases to be harmful. Genrich Altshuller, The Innovation Algorithm page 288.

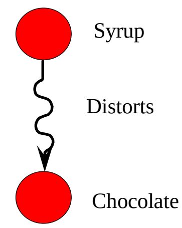
the problem, where the harmful action is done on purpose. Or, if the harmful action were adjustable, could we not identify a useful variant?

Step 2: Identify the knobs that control this now-useful function. Adjust the knobs to boost this now-useful function.

Step 3: Can this new useful function take over for another element in the system which acts upon the given product, thus simplifying the system?

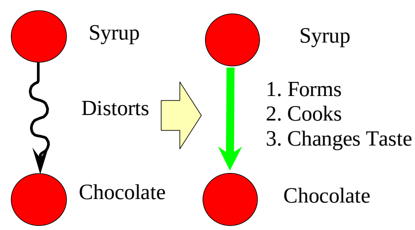
Example—Syrup is Melting Chocolate

In order to increase production of a chocolate factory, the syrup that was normally pumped into the chocolate was heated. This reduced the viscosity, allowing for larger volumes to be pumped through the existing pipes. Unfortunately the heated syrup now distorts the chocolates.



Step 1: Cast the harmful function on the product in a useful context with relation to the given product. If it is difficult to identify a situation then look for situations not related to the problem, where the harmful action is done on purpose. Or, if the harmful action were adjustable, could we not identify a useful variant?

In our case, we can say that the syrup forms or cooks the chocolate. Adjustable distortion is also forming.



Step 2: Identify the knobs that control this now-useful function. Adjust the knobs to boost this now-useful function.

Some of the knobs are the temperature and gradient of the syrup, the flavor of the syrup.

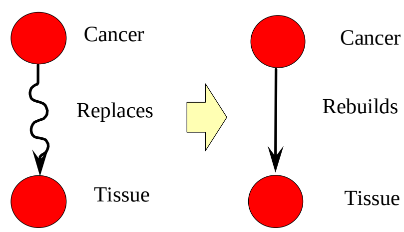
Step 3: Can this new useful function take over for another element in the system which acts upon the given product, thus simplifying the system?

We will consider allowing the syrup to partially form the chocolate, rather than other elements in the system.

Example—Cancer Repair

Cancer is normally thought of as a very harmful element in the body. What harm does it cause? Cancer causes a number of harmful effects including the replacement or invasion of healthy tissue.

Step 1: Cast the harmful function on the product in a useful context with relation to the given product. If it is difficult to identify a situation then look for situations not related to the problem, where the harmful action is done on purpose. Or, if the harmful action were adjustable, could we not identify a useful variant?



In our case, we can say that the cancer repairs the tissue.

Step 2: Identify the knobs that control this now-useful function. Adjust the knobs to boost this now-useful function.

The knobs that would make this useful are the ones that turn cancer on and off. This will likely take more research so this innovation will need to wait.

Step 3: Can this new useful function take over for another element in the system which acts upon the given product, thus simplifying the system?

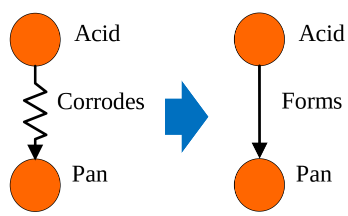
We will consider allowing the cancer cells to repair a heavily damaged organ.

Example—Acid Container

Using this approach, we would like to convert the corrosion of the container into an action that is useful. If possible, it would be nice to make it useful to the container.

Step 1: Cast the harmful function on the product in a useful context with relation to the given product. If it is difficult to identify a situation then look for situations not related to the problem, where the harmful action is done on purpose. Or, if the harmful action were adjustable, could we not identify a 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 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.

Step 2: Identify the knobs that control this now-useful function. Adjust the knobs to boost this now-useful function.

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.

Step 3: Can this new useful function take over for another element in the system which acts upon the given product, thus simplifying the system?

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.

Example—Pile Driving

We would like to cast the pushing action of the soil in a new light. We don't want to just reduce the effect of the soil pushing against the pile, but rather make it useful.

Step 1: Cast the harmful function on the product in a useful context with relation to the given product. If it is difficult to identify a situation then look for situations not related to the problem, where the harmful action is done on purpose. Or, if the harmful action were adjustable, could we not identify a 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.

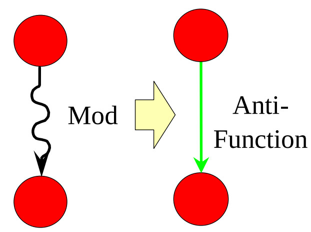
Step 2: Identify the knobs that control this now-useful function. Adjust the knobs to boost this now-useful function.

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.

Step 3: Can this new useful function take over for another element in the system, thus simplifying the system?

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

L3-Reframe as Own Anti Function



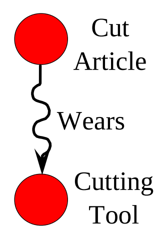
We are going to try to reverse the harmful function[9] and perform a useful anti-function. In this first attempt, we are going to allow for the possibility of using any method from the Table of Knobs (object attributes). It should be noted that when we do this, we get more functionality from our existing elements [10] and turn harm into good[11]. The effect of this may be similar to some of the other methods.

Method

Step 1: Identify the anti-function. Would this be considered a useful function in the system?

Step 2: Now that the anti-function has been identified, we boost this function. Use any of the methods from the Table of Knobs to boost this now-useful function. We may need to consider modifications to other elements in the system. In the end, the system must become simpler, or the solution is not a good one.

Example—Self Sharpening Tools



The action of cutting and shaping tools causes them to become dull. Drills, saws and shears need to be periodically sharpened. This sharpening action takes time and is often never performed, especially when the tools are used only occasionally. In this case, the harmful function is the material being cut is wearing the cutting tool.

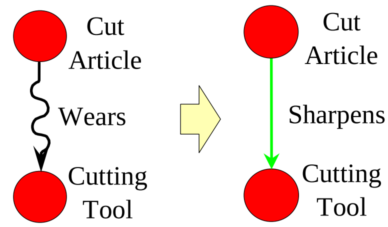
9 Inventive Principle #13—Do It in Reverse: Instead of the direct action dictated by a problem, implement an opposite action (i.e., cooling instead of heating). Make the movable part of an object, or outside environment, stationary and stationary part moveable. Turn an object upside-down. Genrich Altshuller, The Innovation Algorithm page 287.

10 Inventive Principle #6—Universality: an object can perform several different functions ; therefore, other elements can be removed. Genrich Altshuller, The Innovation Algorithm page 287.

11 Inventive Principle #22—Convert Harm Into Benefit: Utilize harmful factors - especially environmental to obtain a positive effect. Remove one harmful factor by combining it with another harmful factor. Increase the degree of harmful action to such an extent that it ceases to be harmful. Genrich Altshuller, The Innovation Algorithm page 288.

Step 1: Identify the anti-function. Would this be considered a useful function in the system?

The anti-function of wearing the cutting tool is to sharpen it.



Step 2: Now that the anti-function has been identified, we boost this function. Use any of the methods from the Table of Knobs to boost this now-useful function. We may need to consider modifications to other elements in the system. In particular, it may be necessary to modify the product slightly in order for this to work. In the end, the system must become simpler, or the solution is not a good one.

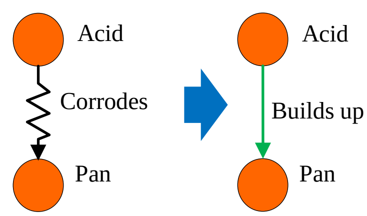
At this point, we would be looking for various ways to make the cut article sharpen the tool. This seems quite unusual and maybe impossible. However, the ability of wearing surfaces to sharpen the tool is known in nature where animal claws and teeth actually become sharper with use. This is possible because the outer layers of the claws and teeth are made from softer materials than the inner layers. The innermost layers are the hardest. The action of wearing away the outer layers causes the harder inner layers to be exposed which make the claws very sharp. Self-sharpening tools employ this same principle to keep drills and saw blades very sharp during use.

Example—Acid Container

We want to find a way to actually reverse the effect of the acid.

Step 1: Identify the anti-function. Would this be considered a useful function in the system?

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



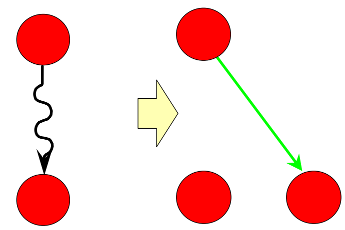
Step 2: Now that the anti-function has been identified, we boost this function. Use any of the methods from the Table of Knobs to boost this now-useful function. We may need to consider modifications to other elements in the system. In the end, the system must become simpler, or the solution is not a good one.

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.

Example—Pile Driving

In this example, the anti-function of pushing the pile is pulling the pile. We have already considered this case when we looked at a useful variant of the function of pushing.

L3-Make Useful on Another Product



One man's trash is another man's treasure. In this method, we will try to find a way to make the harmful function perform a useful function on another element in the system. Mostly, we look around the environment to see if the harmful function is actually useful on another product in the system. It should be noted that when we do this, we get more functionality from our existing elements [12] and turn harm into good[13]. The effect of this may be similar to some of the other methods.

Method

Step 1: Identify a useful variant of the harmful action

Step 2: Identify a second object in the environment that could use the useful variant because a harmful action is being performed on it.

Example—Pipe Loss from Acid

Waste acid is transported in pipes throughout a plant. Even though the pipes are made from non-corrosive materials, they still are eaten away by the acid and eventually need to be replaced. Replacing the waste pipes is very expensive.

Step 1: Identify a useful variant of the harmful action

The useful variant of being eaten away is that the acid cleans the pipes.

Step 2: Identify a second object in the environment that could use the useful variant because a harmful action is being performed on it.

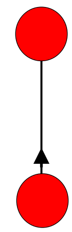
Nearby are waste pipes that transport materials that deposit on the inside of the pipe. These pipes need the cleaning action. Alternately switching the waste products between the two pipes allows the deposits to protect the pipes and the acid to wear away the deposits. Note that we could have looked at the pipes with the deposits as a method of coating the pipes to protect them. We could have then looked around and asked what needed this protection (recall that protecting is a confusing function).

12 Inventive Principle #6—Universality: an object can perform several different functions ; therefore, other elements can be removed. Genrich Altshuller, The Innovation Algorithm page 287.

13 Inventive Principle #22—Convert Harm Into Benefit: Utilize harmful factors - especially environmental to obtain a positive effect. Remove one harmful factor by combining it with another harmful factor. Increase the degree of harmful action to such an extent that it ceases to be harmful. Genrich Altshuller, The Innovation Algorithm page 288.

L3-Reverse the Fields or Action

One of the simplest ways to reverse or create the anti-function is to directly reverse the direction of action of the fields[14]. The function may change when the fields are reversed. This is particularly useful when the physical phenomenon that delivers the harmful action is primarily performed by few fields and objects.



Method

Step 1: Identify the fields that cause the harmful action.

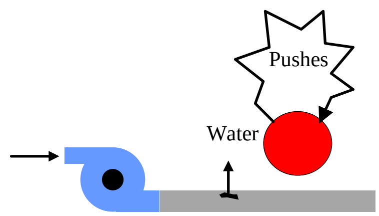
Step 2: What constitutes the reverse of the fields?

Step 3: What is the action performed relative to? Change that instead.

Step 4: Boost the anti-function to make it completely useful.

Example—Foundry Explosions

Consider a situation where water escapes from cooling pipes into the refractory bricks of a smelter. The water explodes upon contact with the bricks. One of the harmful functions is that the pressurized water pushes itself out of the pipe



Step 1: Identify the fields that cause the harmful action.

The field is the pressure field of the water in the pipe.

Step 2: What constitutes the reverse of the fields?

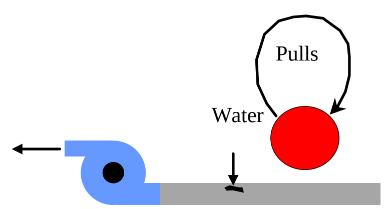
Reversing the fields means that the water in the pipe is under vacuum. The pump pulls the water rather than pushing it.

Step 3: What is the action performed relative to? Change that instead.

It pushes relative to the hole position of the pipe. This would imply that the pipe should move instead of the water. This does not yield a useful solution.

Step 4: Boost the anti-function to make it completely useful.

Here we reverse the pressure field and cause vacuum in the line. This is effectively done by having the pump draw the water through the line rather than pushing it.

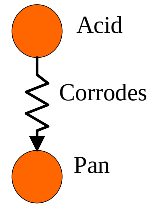


14 Inventive Principle #13—Do It in Reverse: Instead of the direct action dictated by a problem, implement an opposite action (i.e., cooling instead of heating). Make the movable part of an object, or outside environment, stationary and stationary part moveable. Turn an object upside-down. Genrich Altshuller, The Innovation Algorithm page 287.

Example—Acid Container

In the TRIZ Pow

Step 1: Identify the fields that cause the harmful action.



The field that causes the harmful action is the potential created between the pan and other metals in the system.

Step 2: What constitutes the reverse of the fields?

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

Step 3: What is the action performed relative to? Change that instead.

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.

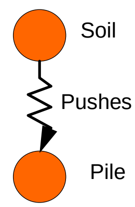
Step 4: Boost the anti-function to make it completely useful.

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

Example—Pile Driving

If possible, we would like to reverse the pressure and friction fields on the pile to make it easier to drive.

Step 1: Identify the fields that cause the harmful action.



The fields that perform the harmful action is the pressure field at the tip of the pile and the friction fields along the pile, including the tip. The pressure fields become higher as the tip is driven deeper.

Step 2: What constitutes the reverse of the fields?

The reverse of the field would be that a tension field is formed at the tip of the pile rather than a compression field. The soil would pull the pile along. Very high tension fields can be formed in materials when they are heated and then cooled. The soil, itself, puts itself into tension. No useful solution is found.

Step 3: What is the action performed relative to? Change that instead.

We try to solve this another way be reversing the action. The action of pushing back is that the soil and pile compress relative to the direction of the driven pile. The reverse of this is that the soil would go into tension when the pile was driven. No useful solution is found.

Step 4: Boost the anti-function to make it completely useful.

Not applicable.

L3-Boost an Existing Weak Variant

Sometimes an object will perform a harmful function and a useful variant at the same time[15]. The useful function may be occurring at such a low degree that it is not recognized. Boosting the useful variant effectively eliminates the harmful function.

Method

Step 1: Is the useful variant of the harmful function already performed along with the harmful function, but so slightly as to not be noticed?

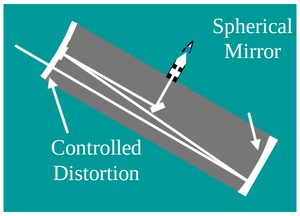
Step 2: Is the anti-function performed with the harmful function but not in equilibrium? Boost the anti-function.

Step 3: Is the harmful function useful any place on the product or on other elements to the least degree? Boost this function.

Example—Telescope Dust Cover

A telescope uses a transparent dust cover. Small irregularities in the cover distort the incoming light. The distortions could be used to correct the effect of a spherical (non-parabolic) mirror which would be cheaper to fabricate.

Step 1: Is the useful variant of the harmful function already performed along with the harmful function, but so slightly as to not be noticed?



Some of the distortions actually help to focus the light. Can this be used if it were boosted? It is possible to design the dust cover so as not to distort. In fact, in working with the reflecting mirror the light can be focused. A further refinement is to recognize how the reflecting mirror can be modified to help the situation. A spherical mirror is much easier to produce. The effect of the dust cover can allow the spherical mirror to focus the light like a parabolic mirror as in a meniscus telescope. (It should be noted that a meniscus telescope typically focuses the light off of a reflecting piece on the cover and back through a hole in the spherical mirror.

Step 2: Is the anti-function performed with the harmful function but not in equilibrium? Boost the anti-function.

No anti-function is detected.

Step 3: Is the harmful function useful any place on the product or on other elements to the least degree? Boost this function.

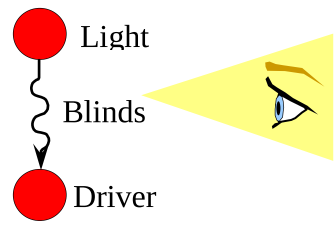
No useful place is noticed.

15 The idea for this comes from the telescope example shown with this method. The inventor notices a distortion of the glass and then that the distortion can be used to correct the effect of spherical (not parabolic) mirrors. The Innovation Algorithm by G.S. Altshuller, Technical Innovation center. First Edition 1999. Page 32

Example—Blinding Car Lights

Consider the blinding light that is seen from oncoming traffic with their high beams on.

Step 1: Is the useful variant of the harmful function already performed along with the harmful function, but so slightly as to not be noticed?

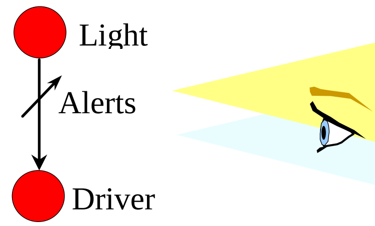


The useful variant that occurs at the same time as blinding is to alert the driver that a car is oncoming. This can be especially useful if something is wrong with the driver of the oncoming car or the car itself.

Step 2: Is the anti-function performed with the harmful function but not in equilibrium? Boost the anti-function.

This does not apply in this instance.

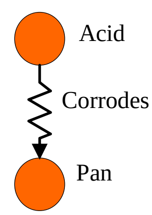
Step 3: Is the harmful function useful any place on the product or on other elements to the least degree? Boost this function.



We have already stated that alerting the driver is already occurring and useful. If something is wrong with the oncoming car or driver, the lights can alert the occupants of the oncoming car that something is wrong and that they might want to take evasive action. For instance, if the driver is intoxicated, it might be useful to know. The lights might fluctuate in color or change direction slightly to alert the oncoming driver of the danger.

Example—Acid Container

Is it possible that a weak but useful variant of corrosion on the pan is occuring?



Step 1: Is the useful variant of the harmful function already performed along with the harmful function, but so slightly as to not be noticed?

The useful variant of "corroding" is "forming". The useful action of forming the pan is occurring so long as the material is removed uniformly. Since we have already considered this, we will not consider it here.

Step 2: Is the anti-function performed with the harmful function but not in equilibrium? Boost the anti-function.

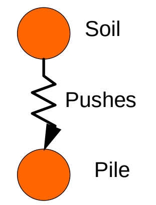
This presents an interesting possibility. At a microscopic scale, molecules of the pan are being ripped away by the acid while molecules of the metal are being forced back to the surface. This is true in all chemical reactions. The reason that corrosion occurs is because more material is being pulled 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.

Step 3: Is the harmful function useful any place on the product or on other elements to the least degree? Boost this function.

No solution is found.

Example—Pile Driving

Is it possible that a useful variant of pushing is occurring at the same time as the harmful variant?



Step 1: Is the useful variant of the harmful function already performed along with the harmful function, but so slightly as to not be noticed?

In this case, we are asking if pulling is occurring anywhere on the pile? No place is found.

Step 2: Is the anti-function performed with the harmful function but not in equilibrium? Boost the anti-function.

We are asking if pulling and pushing are occurring at the same time, perhaps at a molecular level. Nothing solution is found.

Step 3: Is the harmful function useful any place on the product or on other elements to the least degree? Boost this function.

Is the action of pushing useful anyplace on the pile? So instance is found.

L3-Aesthetic Incorporation

Many forms of art require the artist to incorporate flaws which inadvertently occur during the creation of the art. A small and accidental mark on an India Ink drawing becomes the beginning a bush, etc. In effect, we are increasing the harmful function until it ceases to be harmful[16].

Method

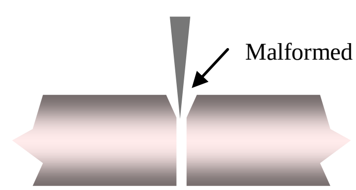
Step 1: Can the flaw, caused by the harmful modification be directly incorporated aesthetically?

Step 2: Multiply the flaw. Make different patterns with the multiplied flaw. What pattern looks the best or performs a useful function?

Step 3: Can this aesthetic incorporation perform a useful function?

Example—Cutting Plastic Tubing

A plastic tube is cut. In the process, the tube is malformed where the blade begins to cut.

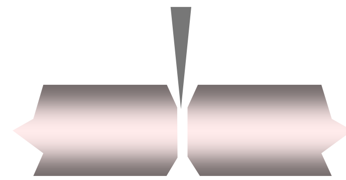


Step 1: Can the flaw, caused by the harmful modification be directly incorporated aesthetically?

No way is seen.

16 Inventive Principle #22—Convert Harm Into Benefit: Utilize harmful factors - especially environmental to obtain a positive effect. Remove one harmful factor by combining it with another harmful factor. Increase the degree of harmful action to such an extent that it ceases to be harmful. Genrich Altshuller, The Innovation Algorithm page 288.

Step 2: Multiply the flaw. Make different patterns with the multiplied flaw. What pattern looks the best or performs a useful function?



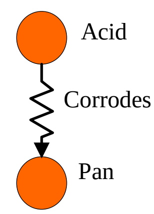
If the pattern is repeated, it becomes a rolled cut

Step 3: Can this aesthetic incorporation perform a useful function?

The bevel can act to guide elements that might be attached to the tube ends.

Example—Acid Container

If the harmful function of corrosion only altered the aesthetics we might be able to use this approach.



Step 1: Can the flaw, caused by the harmful modification be directly incorporated aesthetically?

This does not apply as aesthetics are not important.

Step 2: Multiply the flaw. Make different patterns with the multiplied flaw. What pattern looks the best or performs a useful function?

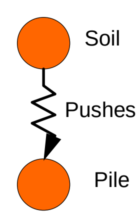
Not applicable in this instance.

Step 3: Can this aesthetic incorporation perform a useful function?

Not applicable in this instance.

Example—Pile Driving

If pushing back on the pile altered the aesthetics of the pile, then we might be able to use this approach.



Step 1: Can the flaw, caused by the harmful modification be directly incorporated aesthetically?

Because we do not care about the aesthetics of pushing the pile, this approach is not viable here.

Step 2: Multiply the flaw. Make different patterns with the multiplied flaw. What pattern looks the best or performs a useful function?

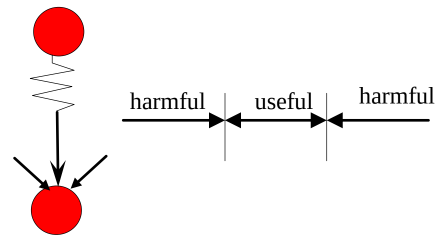
This is not applicable in this instance.

Step 3: Can this aesthetic incorporation perform a useful function?

This is not applicable in this instance.

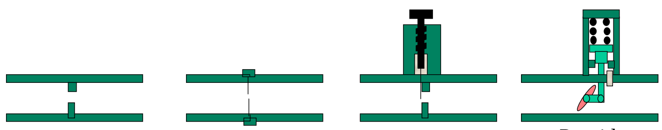
L3-Perform Accurately

Sometimes a useful function becomes harmful when it goes outside of its useful bounds. In this case, it may become useful by simply putting it within bounds.



Line of Evolution

The line of evolution for adjustability[17] is shown below. Once the point of feedback[18] is reached, the added benefits of increasingly good feedback give diminishing returns and the system usually jumps to a new physical phenomenon or to passive control.



Open Loop Control

Open loop control adds an actuator to change the main machine that controls the parameter. A simple controller changes the actuator based upon environmental conditions or time. This is done in avoidance of feeding back the main parameter being controlled because sensing elements can be very expensive.

Closed Loop Control

Closed loop control[19] goes beyond open loop control by providing a device to sense the main parameter that is being controlled. The sensor may sense the derivative of the parameter and then integrate or it may sense the integral of the controlled parameter and then take the derivative. The control scheme then compares the level of the parameter that is being controlled to a reference level and calculates an "error". This error is then used in a controller to provide a signal to the actuator that drives the main "plant". The control laws can be simple or complicated depending upon the accuracy required.

---

17 Inventive Principle #15—Dynamicity: Characteristics of an object or outside environment, must be altered to provide optimal performance at each stage of an operation. If an object is immobile, make it mobile. Make it interchangeable. Divide an object into elements capable of changing their position relative to each other. Genrich Altshuller, The Innovation Algorithm page 288.

18 Inventive Principle #23—Feedback: Introduce feedback. If feedback already exists, change it. Genrich Altshuller, The Innovation Algorithm page 288.

19 Inventive Principle #23—Feedback: Introduce feedback. If feedback already exists, change it. Genrich Altshuller, The Innovation Algorithm page 288.

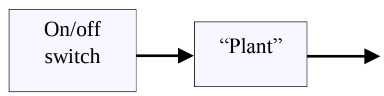
Passive Control

The highest form of control is passive control[20] [21],. The system should ideally use one physical phenomenon for operation and control. The element that senses and controls operates about a critical point at which small changes in input cause large changes in output or large changes in environmental conditions cause small changes in the controlled parameter.

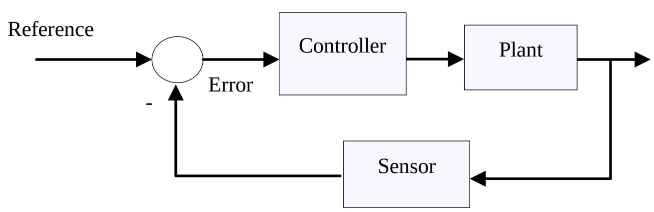
Method

Step 1: Is the anti-function or a useful variant of the harmful function achieved by performing the modification very accurately?

Step 2: Consider Open-Loop Control. Make the tool or product adjustable if it is not already. Consider making the control continuously adjustable. Add an actuator to the tool or product. Add a controller which changes the level of actuation based on operating conditions other than feeding back the main parameter that is being controlled.



Step 3: Use of Closed Loop Control: Does the modification need to be yet more precise? Add a sensor to sense the main parameter that is being controlled. Compare this to a reference level that the parameter is being controlled to. The whole system looks like the figure below. If necessary, increase the number of parameters sensed. Consider increasing the order of the variable sensed (first derivative, second derivative…).



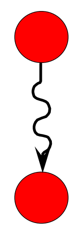
20 Inventive Principle #25—Self-service: An object must service itself and carry-out supplementary and repair operations. Make use of waste material and energy. Genrich Altshuller, The Innovation Algorithm page 288.

21 Use of critical points is an extension of Standard 1-2-5. There are many physical phenomena that exhibit critical points. Operation about these critical points allows for large forces to be created which, in turn, can be used for actuation. STANDARD 1-2-5. If it is necessary to decompose a SFM with a magnetic field, the problem is solved by using physical effects, which are capable of “switching off” ferromagnetic properties of substances, e.g. by demagnetizing during an impact or during heating above Curie point. Notes: The magnetic field may appear at the right moment if a system of magnets compensating the effect of each other's field is used. When one of the magnets is demagnetized, a magnetic field arises in the system. Example: During welding, it is difficult to insert a ferromagnetic powder in the welding zone: an electromagnetic field of a welding current makes the particles move away from the welding zone. It is proposed to heat the powders above the Curie point to make them non-magnetic.

Step 4: Use of Passive Control: Identify a physical phenomenon that senses the parameter that is being controlled and automatically urges the plant to change the parameter being controlled. Identify the critical point around which the system will control the main parameter to the desired level then move the critical point to the desired control point.

Critical Points	Human
Sheer Strength	Temperature threshold
Ultimate Strength	Pressure threshold
Tip Angle	Auditory threshold
Static Friction	Olfactory threshold
Adhesive Failure point	Personal space violation
Zero Buoyancy	Speed threshold
Triple point	Altitude threshold
Surface Tension	Visual thresholds
Resonant Frequency	Startling point
Spark point	Discomfort (A pattern or perception that something is out of place)
Freezing point	Equilibrium threshold
Boiling point	
Curie temperature	

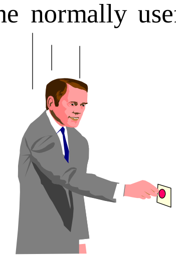
Example—Hot Air Temperature in a Room

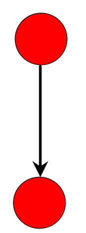


If the temperature of a room becomes too hot, then it performs a harmful function on the occupants.

Step 1: Is the anti-function or a useful variant of the harmful function achieved by performing the modification very accurately?

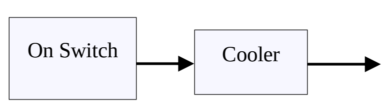
Bringing the temperature into bounds makes the normally useful function of warming useful again.



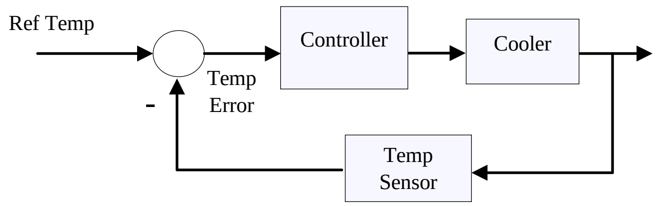


Step 2: Consider Open-Loop Control. Make the tool or product adjustable if it is not already. Consider making the control continuously adjustable. Add an actuator to the tool or product. Add a controller which changes the level of actuation based on operating conditions other than feeding back the main parameter that is being controlled.

An open-loop control actuates a heating or cooling system at regular time intervals or times. In this case, the “actuator” is a cooler which can be turned on and off. The controller turns the cooler on in the morning and off at dusk.



Step 3: Use of Closed Loop Control: Does the modification need to be yet more precise? Add a sensor to sense the main parameter that is being controlled. Compare this to a reference level that the parameter is being controlled to. The whole system looks like the figure below. If necessary, increase the number of parameters sensed. Consider increasing the order of the variable sensed (first derivative, second derivative…).



In most homes, the cooling/heating needs to be fairly accurate. A temperature sensor is added. The room temperature is fed back and compared to a reference temperature.

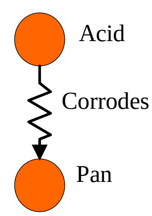
Step 4: Use of Passive Control

Identify a physical phenomenon that senses the parameter that is being controlled and automatically urges the plant to change the parameter being controlled. Identify the critical point around which the system will control the main parameter to the desired level then move the critical point to the desired control point.

Many substances experience phase transitions which occur at critical temperatures. These phase change materials can have large capacities to store and release energy. Such materials have been incorporated into building materials which have critical points around the temperatures that humans find comfortable.

Example—Acid Container

If the action of corrosion were harmful because it was out of bounds then we could make it useful by placing it within bounds.



Step 1: Is the anti-function or a useful variant of the harmful function achieved by performing the modification very accurately?

This approach does not appear to apply because there is no range of corroding the pan that is helpful.

Step 2: Consider Open-Loop Control. Make the tool or product adjustable if it is not already. Consider making the control continuously adjustable. Add an actuator to the tool or product. Add a controller which changes the level of actuation based on operating conditions other than feeding back the main parameter that is being controlled.

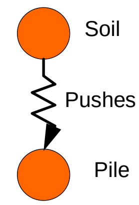
This is not applicable.

Step 3: Use of Closed Loop Control: Does the modification need to be yet more precise? Add a sensor to sense the main parameter that is being controlled. Compare this to a reference level that the parameter is being controlled to. The whole system looks like the figure below. If necessary, increase the number of parameters sensed. Consider increasing the order of the variable sensed (first derivative, second derivative…).

This approach does not appear to be applicable.

Example—Pile Driving

If the action of pushing on the pile was harmful because it was out of bounds then we could make it useful by placing it within bounds.



Step 1: Is the anti-function or a useful variant of the harmful function achieved by performing the modification very accurately?

This approach does not appear to apply to this problem because there is no range of pushing back on the pile that is helpful.

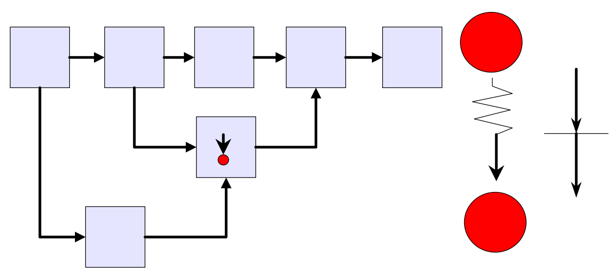
Step 2: Consider Open-Loop Control. Make the tool or product adjustable if it is not already. Consider making the control continuously adjustable. Add an actuator to the tool or product. Add a controller which changes the level of actuation based on operating conditions other than feeding back the main parameter that is being controlled.

This does not apply.

Step 3: Use of Closed Loop Control: Does the modification need to be yet more precise? Add a sensor to sense the main parameter that is being controlled. Compare this to a reference level that the parameter is being controlled to. The whole system looks like the figure below. If necessary, increase the number of parameters sensed. Consider increasing the order of the variable sensed (first derivative, second derivative…).

This does not apply.

L3-Harmonize Harmful Stages



This method comes from considerations of harmonizing functions,[22] whether they be useful or harmful. Sometimes, a harmful function becomes useful[23] when it is performed in a different sequence or time than it is normally performed. It may be necessary for a completely different job, so it is important to expand the thinking in time.

A harmful function may become useful by breaking it up and performing the different parts at times when they are useful. Functions are shorthand for processes which can always be broken into stages. A harmful action or stage can be stored and then used when it is useful. Sometimes, a harmful action can be combined with other harmful actions to create a useful action[24]. If it is not obvious that this new action is useful, it may be possible to find a useful variant of the combined action and boost that useful variant.

22 Creativity as an Exact Science—the Theory of the Solution of Inventive Problems, G.S Altshuller, Gordon and Breach, page 226.

23 Inventive Principle #22—Convert Harm Into Benefit: Utilize harmful factors - especially environmental to obtain a positive effect. Remove one harmful factor by combining it with another harmful factor. Increase the degree of harmful action to such an extent that it ceases to be harmful. Genrich Altshuller, The Innovation Algorithm page 288.

24 Inventive Principle #22—Convert Harm Into Benefit: Utilize harmful factors - especially environmental to obtain a positive effect. Remove one harmful factor by combining it with another harmful factor. Increase the degree of harmful action to such an extent that it ceases to be harmful. Genrich Altshuller, The Innovation Algorithm page 288.

Method

Step 1: Break harmful functions into stages using a process map or storyboard. Breaking the functions into finer and finer stages may create more possibilities.

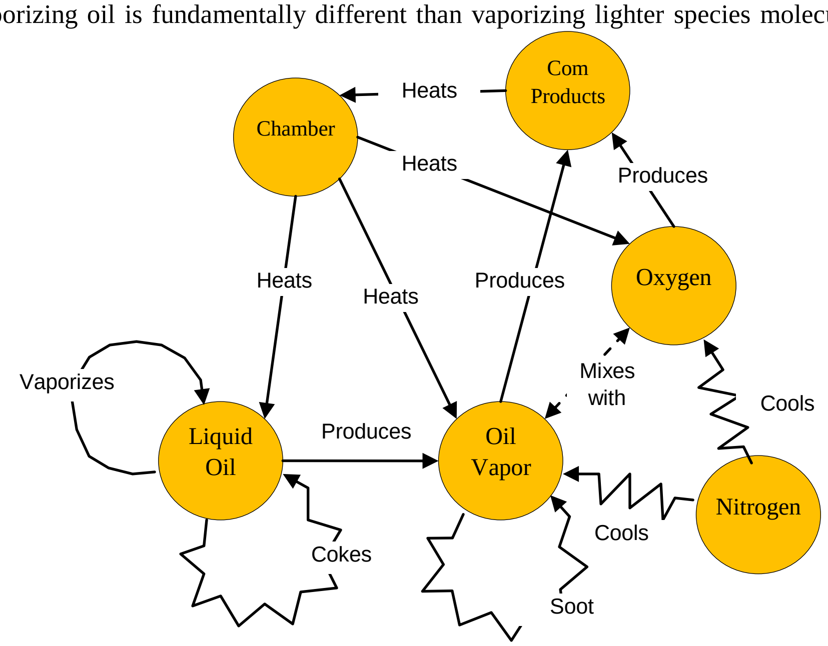
Step 2: Move stages around so that unproductive or harmful stages become productive. Look for opportunities for where two harmful actions can be combined with useful results. Add steps that make the harmful effects into useful effects.

Step 3: Consider the alternative route of storing the effects of harmful functions for use at a later time. Remember that energy can be stored, temporarily in oscillations.

Example—Combustion of Cooking Oils

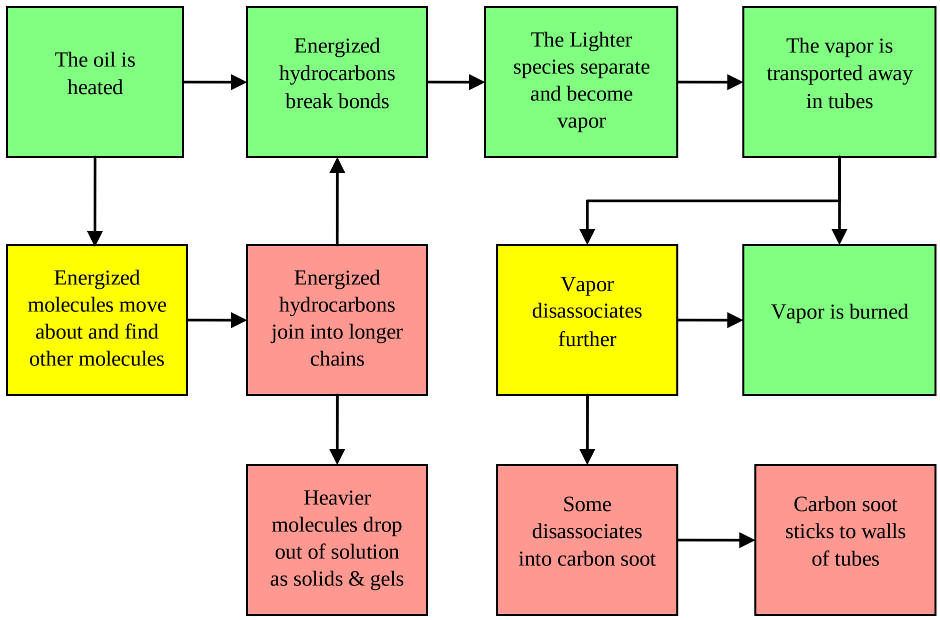
In developing countries such as Haiti, the country is deforested due to the local habit of burning plant materials such as wood. Local people forage the area to find any burnable wood. As a result, satellite photos show a demarcation between Haiti and the Dominican Republic where half of the island is deforested. One way to handle this is to burn non-edible vegetable oils. Some plants give off large amounts of these oils. The problem is that the oils must be heated to a high temperature in order to create combustion gases. Unfortunately, the temperature required to form the combustion gases is the same temperature that initiates coking. Coking is the chemical reaction which occurs between lighter components that creates larger and larger molecules that settle out of the oil as gels and solids. In this case, these solids may settle out of the vapors as soot in the transmission pipes. These soot and coking deposits not only must be cleaned out of the cooking stoves, but they effectively increase the cost of the oil since they represent oil that is never burned. How can the cleaning and loss of oil be avoided?

Vaporizing oil is fundamentally different than vaporizing lighter species molecules like



gasoline. In the case of oil, the oil must be chemically changed by the breaking of molecular bonds. The lighter species of hydrocarbon are able to be vaporized and then transported as vapor and burned. In the case of gasoline, a liquid is turned into a gas by energizing it sufficiently to become vapor. No chemical change is required. Once vaporized, it is easily transported and burned. The temperature required to vaporize gasoline is not high enough to change chemical bonds. In the case of oil, it is necessary to break chemical bonds in order to create species of hydrocarbons that are capable of being vaporized. The problem is that while some molecules are being chemically disassociated into lighter vapor molecules, others are being combined into larger, more solid molecules.

Step 1: Break harmful functions into stages using a process map or storyboard. Breaking the functions into finer and finer stages may create more possibilities.

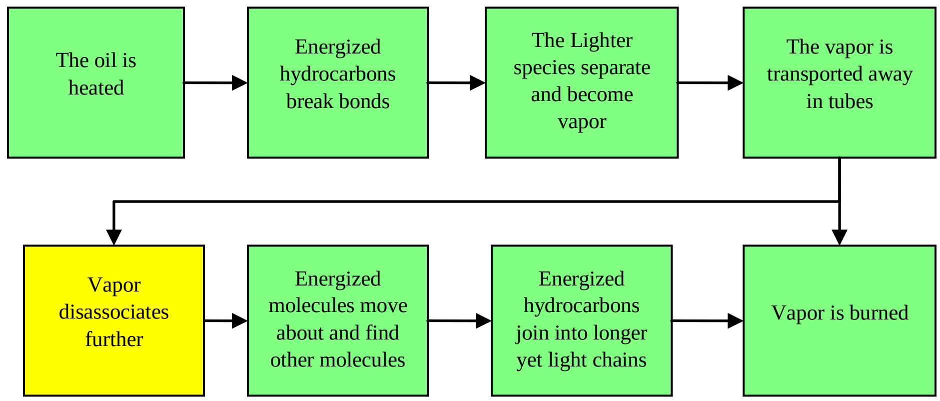


The green boxes represent steps that are either useful or at least, not harmful in themselves. Yellow boxes are precursors to harmful functions but are not harmful yet.

What we notice is that the energizing of molecules is a double edged sword. It breaks bonds and joins bonds. In general, we would like this to only go one way to form smaller and smaller hydrocarbon chains. Breaking hydrocarbons into smaller and smaller molecules only works to a point. Problems arise when single carbon atoms are left on the walls of tubes. If the precursors were not allowed to progress then the harmful functions can't occur.

Step 2: Move stages around so that unproductive or harmful stages become productive. Look for opportunities for where two harmful actions can be combined with useful results. Add steps that make the harmful effects into useful effects.

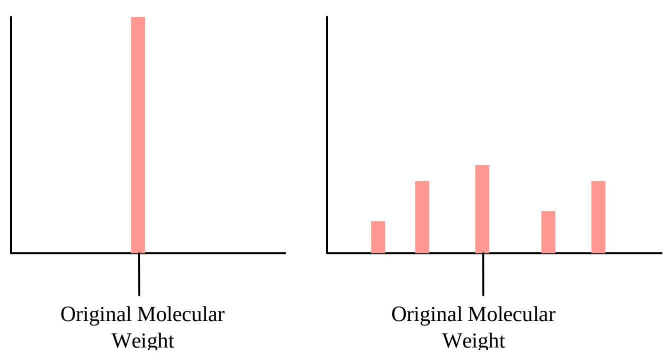
The harmful stage of joining the hydrocarbons into longer chains might be useful to combine species during the transfer of vapor to make sure that carbon does not settle out on the walls of the tubes. Let's see what this looks like.



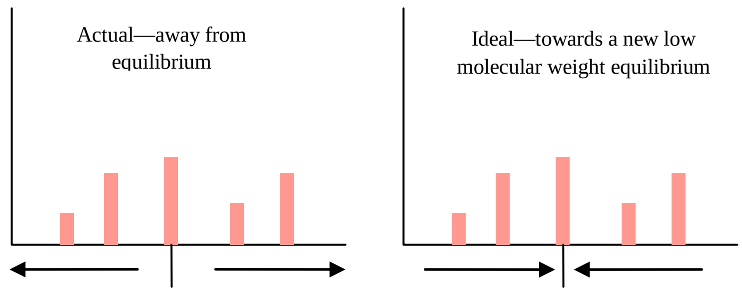
First we notice that disassociation and joining of molecules are just fine as long as this is performed in a way that drives to equilibrium where the molecules are of a light species that can be vaporized. If the molecules become too small, then they should be driven back to the larger equilibrium species. If the molecule is too large, then they should be disassociated into smaller species. We know the potential for this exists because the disassociation and joining occur at the same time.

Up to this point, we have used the process to drive the thinking and expectations. It all seems reasonable at the surface, but now we must look deeper. Let's perform a thought experiment. Let's play like we are starting with one species of molecule which we would like to disassociate into lighter molecules which are driven off as gas. We can characterize this species with a molecular weight. We note that each species will tend to disassociate into lighter species and combine with other molecules to form heavier species. Let's say that we heat this single species for 10 minutes and then come back and look at what we have.

When we measure the new molecular weights, we find that our single species has now become other species which have higher and lower molecular weights. Each of the new species has their own tendency to disassociate or combine with the resulting molecules, thus spreading the distribution to very light and very heavy species over the course of a long period of time.



Remember that our hope was to find a way that the combination of molecules needed to be worked with the disassociation of molecules to drive to equilibrium. In the thought experiment, combination and disassociation do happen at the same time; however they drive to broader species rather than to equilibrium.



At this point, we do not know how to achieve the ideal. Mostly what we have accomplished is to create new insights and a new ideal that we would like to drive towards. If further steps in our systematic innovation process, we would be now looking at making the chemistry useful rather than harmful. We would be trying to understand the parameters that we could manipulate or even new objects that we might introduce that would allow this to happen.

Step 3: Consider the alternative route of storing the effects of harmful functions for use at a later time. Remember that energy can be stored, temporarily in oscillations.

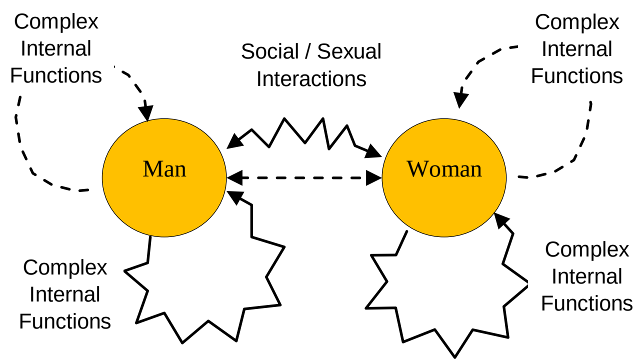
The main harmful effect of the joining of hydrocarbons is coke. The main harmful effect of disassociation is carbon depositing out on the wall of the tubes. How might we store the coke or the carbon on the tubes for later use? In both cases, it may be possible to burn the solid hydrocarbons later if they were in suitable form. For instance, what if the coke or carbon could be formed into small, burnable "sticks"? It is interesting to note that chimney fires are caused by this same problem. Unburned hydrocarbons and carbon deposit in the chimney flue and then catch fire at a later date creating very hot fires). If this could be harnessed, as a useful function then chimney fires could become useful.

As a final note to this example, we started by showing the idea of harmonizing harmful functions. Had we started this at the beginning, we might be on a totally different path. For instance, we might be considering why vaporization is required in the first place. For instance, if heating is accomplished very rapidly, little speciation will occur.

Example—Cohabitation

Many studies have shown that couples that cohabitate have decreasing satisfaction with their relationship over time. Also some studies indicate increased rates of violence compared to dating and marriage.

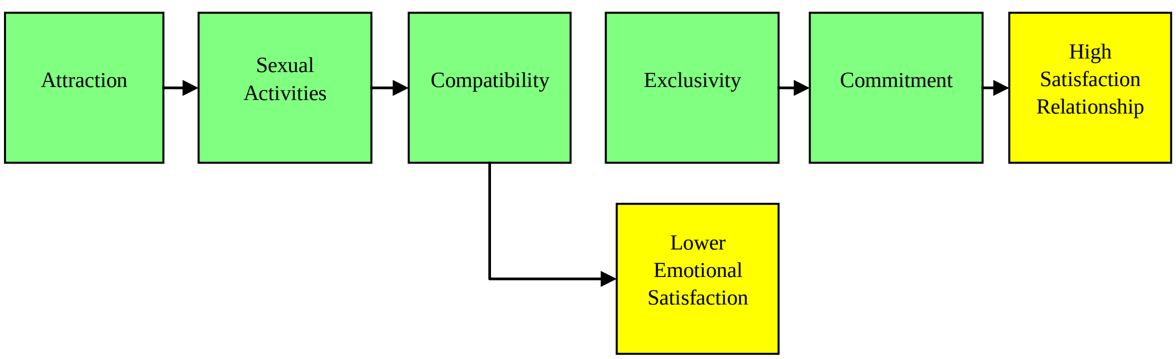
There are complex useful and harmful mental and physical interactions within both the man and the woman as well as harmful and useful sexual interactions between the man and the woman. The useful interactions are shown as less than satisfactory as long as the



relationship is not fulfilling for all involved (including possible offspring). Truthfully, this diagram does not enlighten us very much due to the complexity of thoughts and interactions between the parties. The complex internal functions follow from the social / sexual interactions which we will concentrate on.

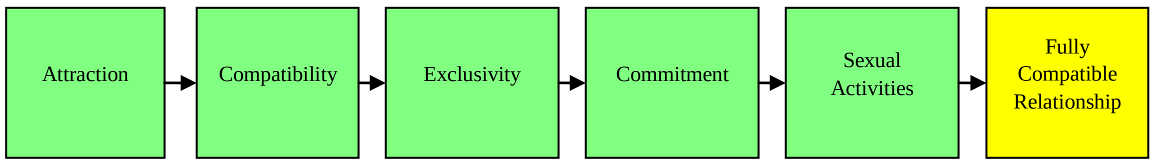
Step 1: Break harmful functions into stages using a process map or storyboard. Breaking the functions into finer and finer stages may create more possibilities.

We get a little more insight from the process diagram below. The sequence of the social and sexual relationships often show that sexual relations predate attempts to establish compatibility, exclusivity, commitment and practical considerations for living together in a family. When sexual relationships are performed early, then the couple delays compatibility, exclusivity and commitment until later. Early sexual activity stunts subsequent steps. Even if marriage eventually occurs, couples that cohabitate express lower satisfaction than married couples that wait until marriage.



Step 2: Move stages around so that unproductive or harmful stages become productive. Look for opportunities for where two harmful actions can be combined with useful results. Add steps that make the harmful effects into useful effects.

Adding the useful functions that were, once held in high esteem allows the act of sex to strengthen relationships rather than to keep, full compatibility, exclusivity and commitment from forming.



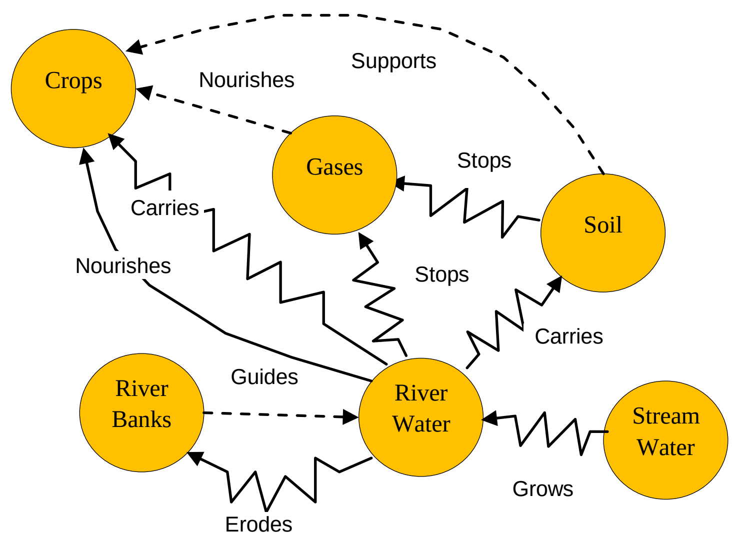
Step 3: Consider the alternative route of storing the effects of harmful functions for use at a later time. Remember that energy can be stored, temporarily in oscillations.

"Storing up" low satisfaction for use later could be construed as "learning" something from a bad relationship that can later be used to form a good relationship. Of course, this depends on the affected party being aware of the harm of co-habitation and what caused it.

Example—Flood Waters

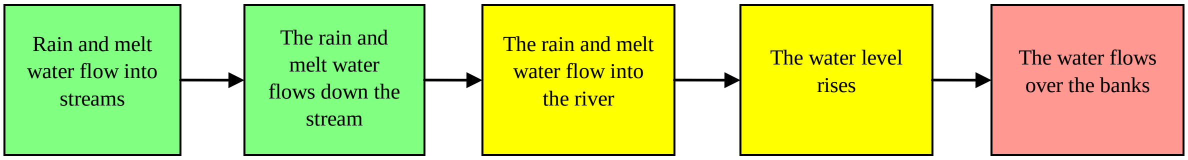
Flood waters destroy manmade structures and croplands. These very same areas are often affected by drought. Let's consider the harmful action of the flood waters.

In this case the river water normally performs the useful function of nourishing the crops.



The river banks guide the river water. When the river carries too much water and overflows the banks, the river then partially guides the water. Then the river separates the crops from atmospheric gases such as carbon dioxide and oxygen. The river water also carries silt which is deposited on the crops also blocks the atmospheric gasses. Eventually, the gases cannot nourish the crops and they die. The water also carries away the soil that supports the crops and then it washes the crops away. Note that all of this starts because of the harmful action of the stream water flowing into the river water. We will focus on this harmful function.

Step 1: Break harmful functions into stages using a process map or storyboard. Breaking the functions into finer and finer stages may create more possibilities.



Step 2: Move stages around so that unproductive or harmful stages become productive. Look for opportunities for where two harmful actions can be combined with useful results. Add steps that make the harmful effects into useful effects.

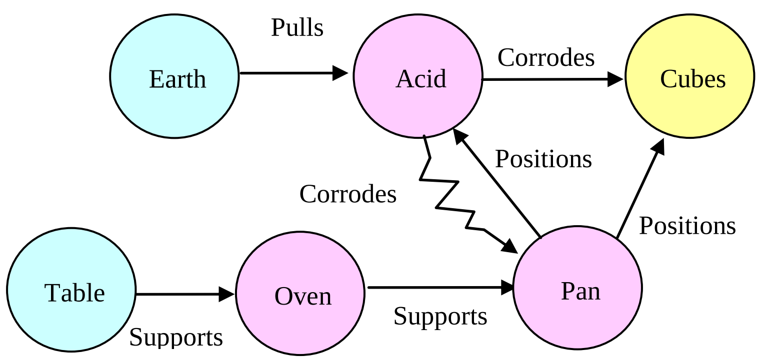
Moving the stages around does not seem to help the problem.

Step 3: Consider the alternative route of storing the effects of harmful functions for use at a later time. Remember that energy can be stored, temporarily in oscillations.

We can store the melt water that covers the fields. We can do this by storing the water for use when it is needed.

Example—Acid Container

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.

$Zn + 2H^{+} + Cl^{--}$ --> $Zn^{++}+Cl2^{--}+ H2\uparrow$

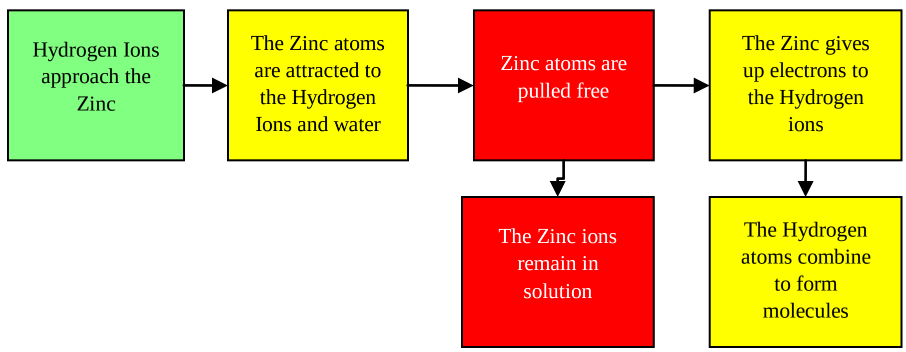
Since the Cl^{--} shows up on both sides of the equation, we can simplify the equation:

$Zn + 2H^{+} \rightarrow Zn^{++} + H_2\uparrow$

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.

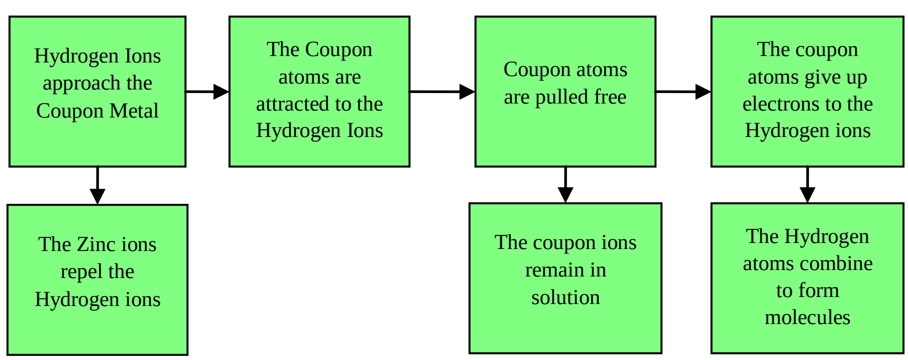
The chemistry does not really indicate the sequence of events. Let's hypothesize what happens. As a hydrogen ion approaches the surface of the metal, the positive charge of the ion attracts the loosely attracted valence electrons in the zinc. The zinc atoms are pulled free from the main body of metal 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.

Step 1: Break harmful functions into stages using a process map or storyboard. Breaking the functions into finer and finer stages may create more possibilities.



Step 2: Move stages around so that unproductive or harmful stages become productive. Look for opportunities for where two harmful actions can be combined with useful results. Add steps that make the harmful effects into useful effects.

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 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.

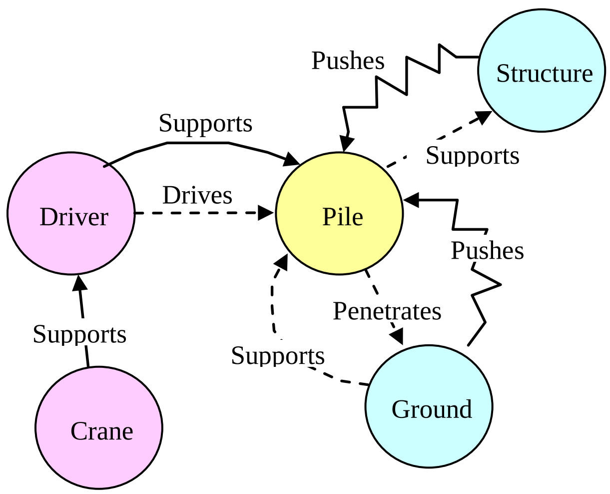


Step 3: Consider the alternative route of storing the effects of harmful functions for use at a later time. Remember that energy can be stored, temporarily in oscillations.

In step 2, we diverted the harmful function from the pan to the coupons, rather than storing the effect. Were we to store the harmful effect, we would be storing the corrosive effect of the acid. The ions would be stored in some fashion to be unleashed at a later time. As long as they could be unleashed on the coupons, this could be useful. The acid, already, effectively stores the ions in concentrated form.

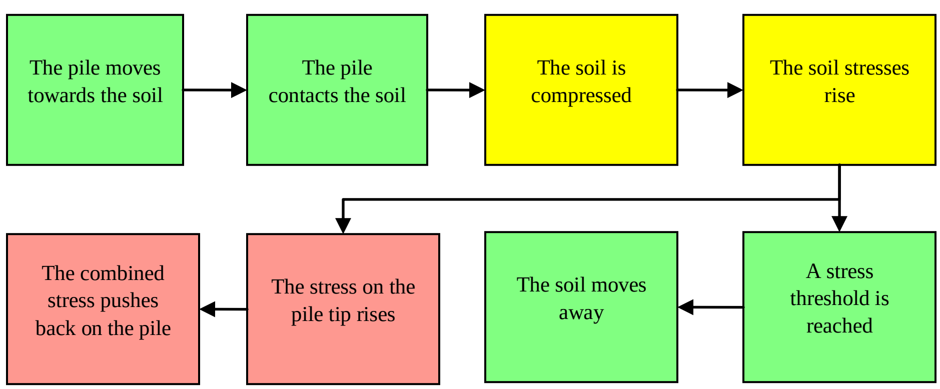
Example—Pile Driving

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



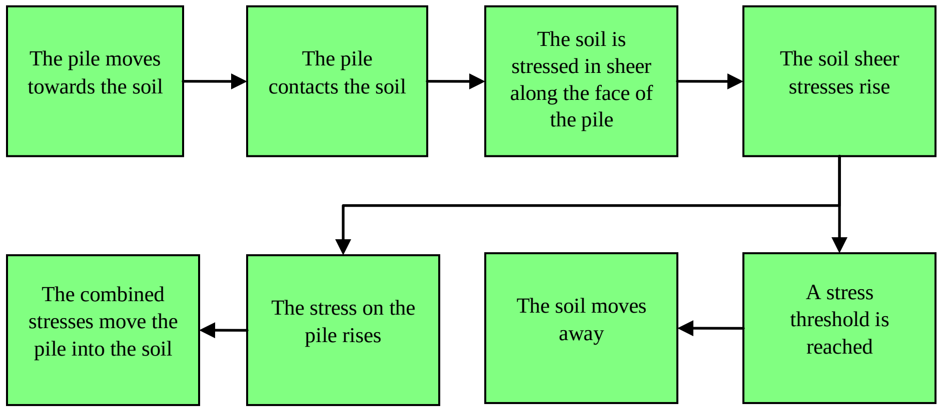
We are considering the harmful function of the ground pushing on the pile. Of course, there is an equal and opposite reaction. The pile also pushes on the ground to penetrate it. The pile actually moves the soil and the soil pushes back.

Step 1: Break harmful functions into stages using a process map or storyboard. Breaking the functions into finer and finer stages may create more possibilities.

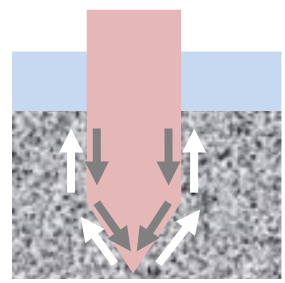


There is an equal and opposite reaction on the pile. The pile needs to move past the soil, but in order for the soil to move, there is a required force or stress that causes it to move. If the pile does not cause it, something else must. For the soil to perform the function of moving itself, there would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

Step 2: Move stages around so that unproductive or harmful stages become productive. Look for opportunities for where two harmful actions can be combined with useful results. Add steps that make the harmful effects into useful effects.



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 sheer 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 sheer stress (rather than compressive stress) is created on the soil, but not by the pile. The sheer 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.



Step 3: Consider the alternative route of storing the effects of harmful functions for use at a later time. Remember that energy can be stored, temporarily in oscillations.

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.

L2-The Ideal Product

The Ideal Product Does not Exist so it cannot be Harmed

A harmful function exists because the product of the function is harmed in some fashion. If the product does not exist, then it cannot be harmed. There are several reasons that the product does not need to exist.

L2-Method

Step 1: Look for the reason that the harmed product exists. If possible remove the reason.

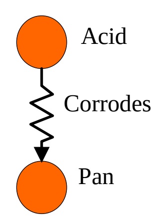
Step 2: Eliminate the harmed product and allow its function to be performed by something else.

Step 3: If the product is a waste product or normally not required in the system, find a way to eliminate the waste product, its path or its source.

Step 4: It is possible that this can lead to the contradiction that the product must and must not exist.

Example—Acid Container

We would like to remove the pan so that it cannot be hurt in any way.



Step 1: Look for the reason that the harmed product exists. If possible remove the reason.

The pan exists to position the acid so that it contacts the pan at all times.

Step 2: Eliminate the harmed product and allow its function to be performed by something else.

We simply remove the pan and ask what else could perform the function of holding the acid. We have already considered that the cubes or coupons can position the acid themselves. If we had not found this another way, we might have discovered this here.

The acid could also hold itself to the cubes. If the acid were very light, then the surface tension of the acid would hold it to the cube. This might be possible with acid foam. A quick Google search turned up hydrochloric acid foam.

Step 3: If the product is a waste product or normally not required in the system, find a way to eliminate the waste product, its path or its source.

The pan is not a waste product so this does not apply.

Step 4: It is possible that this can lead to the contradiction that the product must and must not exist.

The contradiction is that the pan must and must not exist.

Separation in time does not apply since we need the pan while the cubes are corroding and we don't want the pan while the acid is corroding.

Separation gradually would not apply because there is no time in which the acid corrosion does not need to exist.

Separation in space would allow for a non-existing pan and an existing pan. If the non-existing pan were inside the existing pan and the existing pan did not have to touch the acid, then it might work. But how does a non-existing pan hold acid? A non-existing pan would have to be some type of field, which corresponds with separation between the substance and field. A field emanates from the pan and holds the acid at bay. We can consider this later.

Going on, Separation between the parts and the whole would suggest that a non-existing pan is made up of existing pans, or an existing pan is made up of non-existing pans. In this case, perhaps many fields or field types make up the field that holds back the acid. Another possibility is that an existing pan is a carrier for a non-existing pan. Again, this suggests emanating fields.

Separation by direction suggests that the pan exists in one direction but not another. Can't see how this helps.

Separation by perspective does not help because it is not sufficient to only look like the pan does not exist.

Separating by frame of reference suggests that in one reference plane the pan exists, but not in another. This is almost like saying that it exists in one dimension but not another. No answer is found.

Using separation by response of field might exist if the fields around the pan made it not exist to the acid. Perhaps a high enough voltage compared to the cubes would make it effectively not exist to the acid.

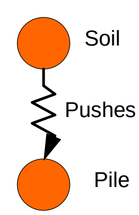
Separating between a substance and field has already been addressed.

Out of all of these, the most promising is the use of a field to keep the acid away from the pan or to make it look to the acid like it does not exist. Question: Is is possible to spin the pan fast enough that heavy negative ions hold to the pan and exclude the lighter hydrogen ions? Of course, the layer would have to be very thin as the charge separation would cause the positive and negative ions to try to hold together. A thin layer might be enough.

Example—Pile Driving

In this case, the harming function of pushing the pile requires that the pile should not exist.

Step 1: Look for the reason that the harmed product exists. If possible remove the reason.



The pile exists to hold the up the building. It is done for aesthetic, as well as structural reasons and so the pile must be used.

Step 2: Eliminate the harmed product and allow its function to be performed by something else.

Removing the pile does not help the situation as we would need another pile to take its place.

Step 3: If the product is a waste product or normally not required in the system, find a way to eliminate the waste product, its path or its source.

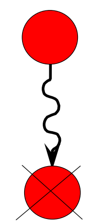
The pile is not a waste product so this does not apply.

Step 4: It is possible that this can lead to the contradiction that the product must and must not exist.

If we say that the pile must not exist so that it may not be pushed back by the soil, but it must exist for aesthetic reasons and to support the building.

L3-Product Not Required

If the product is an unessential part of the super-system or performs a supporting function in the system, then it may not be required. We need to understand why the product is required in the system. What problem does it help resolve? If a Causal Analysis Diagram is being used, it is possible to follow the chain of reasoning back to the problems that the function helps to resolve. Practically, this is done on a Causal analysis diagram by considering the existence of a tool or product of a function as an object attribute that causes the problem. (Seeing the function in the cause effect diagram reminds us that existence of the elements of the function are object attributes that should be considered.) When we consider non-existence of elements in the system (in the side-by-side box), we begin an alternative problem path which leads us to understand why an element was originally required in the system. It is possible to remove the need for the troublesome element and often other elements by resolving a problem elsewhere in the system.



Method

Step 1: If the function is an auxiliary function, then the product may not be required in the system. Determine why the function is required. This may require a causal analysis. What problem does the product solve?

Step 2: Resolve the problem that necessitated the product so that the product is no longer necessary.

Example—Acid Bath

In the beginning chapters of the book, we considered the problem of acid corroding a container that was used to contain blocks of metal and the acid that was used to test the metal blocks for their ability to withstand corrosion.

Step 1: If the function is an auxiliary function, then the product may not be required in the system. Determine why the function is required. This may require a causal analysis. What problem does the product solve?

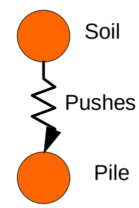
A causal analysis was performed and it was discovered that the container was required to position the acid against the cubes. This function was required in order that a sufficient volume of acid would come in contact with the cube surface under heated conditions. This was necessary because a large amount of corrosion was required for the analysis. This was necessary because the observation technique required a large amount of metal and its attending corrosion to determine its ability to withstand the corrosion. This was required because the weighing of the cubes was performed on a weight scale with low resolution.

Step 2: Resolve the problem that necessitated the product so that the product is no longer necessary.

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.

Example—Pile Driving

Here, we try to determine why the pile is required and then remove the reason.



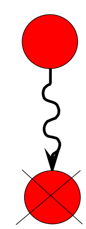
Step 1: If the function is an auxiliary function, then the product may not be required in the system. Determine why the function is required. This may require a causal analysis. What problem does the product solve?

The pile performs a primary function in the system. It controls the position of the structure that it supports. It is required for aesthetic reasons. The pile is there to allow a view of the water underneath the structure.

Step 2: Resolve the problem that necessitated the product so that the product is no longer necessary.

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.

L3-Eliminate the Product

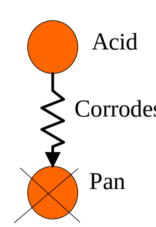


This approach is very direct. Remove the product and find something else in the system which can perform its useful function. This often leads to the consideration of how the function might be performed by existing elements, thus simplifying the system.

Method

Step 1: Eliminate the product and look for something else in the system that can perform the useful function that the product performed.

Example—Acid Container



In the beginning chapters of the book, we considered the problem of acid corroding a container that was used to contain blocks of metal and the acid that was used to test the metal blocks for their ability to withstand corrosion.

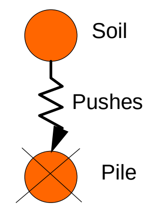
Step 1: Eliminate the product and look for something else in the system that can perform the useful function that the product performed.

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 Driving

Again, we are looking for opportunities to remove the product.

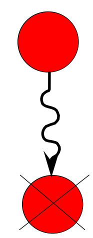
Step 1: Eliminate the product and look for something else in the system that can perform the useful function that the product performed.



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.

L3-Non-Existent Waste Product

Harmful actions can occur on products which are not required in a system. They may be harmful, expended or waste products. If the product has outlived its usefulness, is waste or was never required, consider eliminating it. This is a special case of the proceeding method of simply removing the product and finding something else in the system that can take over the useful function of the product.



Method

Step 1: The product goes away of its own accord by being combined with something else which allows it to dissipate.

Step 2: Consider ways in which the product never existed.

—It is no longer manufactured

—Eliminate the Source of the product

—Eliminate the Path of the product

—Absorb the product into another substance. Absorbent materials might include porous materials[25], fabrics, batting or gel.

Step 3: The waste product remains or becomes useful and is eliminated by its usefulness.

25 Inventive Principle #31—Porous Material: Make an object porous, or use supplementary porous elements (inserts, covers, etc.). If an object is already porous, fill poured in advance with some substance. Genrich Altshuller, The Innovation Algorithm page 289.

Example—Acid Container

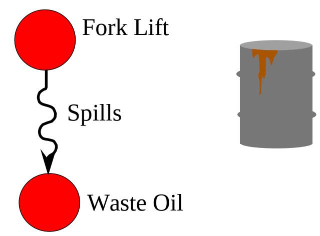
This principle does not apply because the acid is not a waste product.

Example—Pile Driving

This approach does not apply because the pile is not a waste product.

Example—Disposal of Waste Oil

At industrial sites, waste liquid products are often spilled, polluting ground water. This spillage is accomplished by corrosion of the vessels, clumsy handling, etc.



Step 1: The product goes away of its own accord by being combined with something else which allows it to dissipate.

The spent liquid is waste, waiting for recycling.

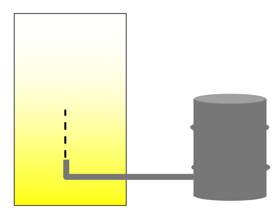
Step 2: Consider ways in which the product never existed.

—*It is no longer manufactured*

—*Eliminate the Source of the product*

—*Eliminate the Path of the product*

—*Absorb the product into another substance. Absorbent materials might include porous materials, fabrics, batting or gel.*



Step 3: The waste product remains or becomes useful and is eliminated by its usefulness.

In this case, the waste oil is immediately burned as an energy source.