Directed Evolution® Instruments
for
Designing Consummate Systems

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Abstract

Throughout history, only a limited number of technological systems have possessed the outstanding qualities that allowed them to enjoy enormous success over an unusually long life. Examples from the last century include: the Ford Model-T automobile, the Douglas DC-3 airplane, the Kalashnikov machine gun, the Singer sewing machine, and the squirrel cage electric motor. These systems cannot be called "ideal" in the TRIZ sense because they were actual systems rather than visionary concepts. Perhaps the best name for them might be *consummate systems*. This paper discusses how the Directed Evolution® approach, the instruments associated with it, and the Ideation Bank of Evolutionary Alternatives™ can help in designing future consummate systems.

Introduction

During the 1970s and 80s we were in complete agreement with Genrich Altshuller, who claimed that the worldwide application of TRIZ could satisfy the most significant human need—namely, creativity. The fact that this assertion could not be proved within the environment of the former Soviet Union was not discouraging, because we believed things would be different in the free world. We now understand that what most people need are the *products* of creativity: good food, nice homes, comfortable cars, exciting entertainment, reliable medicine, etc. The few individuals who are interested in creativity prefer to explore it through games or art. Within these realms, creativity is more exiting and easier to embrace because it is closely connected with emotions and feelings rather than boring technological systems.

As engineers and problem-solving practitioners, we believed that the progress of human society was driven by scientists and technologists. Later we understood that science and technology can only offer possibilities, while the real drivers are social, business, market and other factors. With this in mind, in the mid-1980s we expanded our research effort to include non-technological patterns of evolution.[2]

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[1] Edited by Victoria Roza

[2] Zlotin, Boris, Alla Zusman, Len Kaplan, Svetlana Visnepolschi, Vladimir Proseanic and Sergey Malkin. *TRIZ Beyond Technology. The theory and practice of applying TRIZ to non-technical areas*. Proceedings of TRIZCON 2000, pp. 135-176.

By analyzing the evolution of human needs along with the most significant societal trends in the transition from the Industrial Era to the Informational Era,[3] we concluded the following: The need to obtain solutions to various problems is gradually giving way to the need of an entity (i.e., an individual, organization, society, etc.) to control and manage its destiny.[4]

Controlling one's destiny means, first and foremost, the ability to foresee and avoid problems rather than waiting until they surface to address them.[5] Applied to product development, this approach refers to the ability to design and build systems that remain problem-free throughout their entire life cycle—from the production stage through application by end users and, eventually, to final utilization (recycling).

Throughout history, only a limited number of technological systems have possessed the outstanding qualities that allowed them to enjoy enormous success over an unusually long life. Examples from the last century include: the Ford Model-T automobile, the Douglas DC-3 airplane, the Kalashnikov machine gun, the Singer sewing machine, and the squirrel cage electric motor. For many, including manufacturers and users, these systems were practically ideal in the typical sense of the word, if not in the TRIZ sense.

These systems cannot be called "ideal" in the TRIZ sense because they do not comply with the main requirement for an ideal system – that is, they were brought into existence. Perhaps a better name for them might be *consummate systems*. TRIZ has many rules and instruments designed to help inventors create near-ideal systems. Might these be helpful in designing consummate systems?

Genrich Altshuller introduced ideality in ARIZ-59[6] in the form of the Ideal Final Result (IFR)[7] – an imaginable solution that could be achieved with minimal means and no side effects. He later defined an "ideal machine" as a system that performs a desired function without actually existing. By this definition, the ideal machine is weightless, has zero cost, doesn't occupy any space, or produce any harm, etc. The main underlying consideration was that people do not need systems – rather, they need the useful functions or benefits provided by these systems. And because every system has certain costs and drawbacks associated with it, eliminating the system gets rid of the negative

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[3] Toffler, Alvin. *The Third Wave* (Bantam Books, 1981).

[4] Psychologists insist that there are two types of stress: active and passive. An individual who can actively influence a difficult situation undergoes active stress, which is generally not dangerous to the individual's health; on the contrary, if an individual under stress cannot do much to help resolve the situation, health problems can result.

[5] Science fiction writers have addressed the concept of managing the future numerous times. Probably the most significant are the ideas of Isaac Asimov, who imagined a new science – psychohistory – a revolutionary tool used to ensure the smooth evolution of humanity (Isaac Asimov, Foundation, 1951). In his *Foundation* series, Asimov suggested that psychohistory would be created hundreds of thousand of years in the future because, by then, human civilization would be spread throughout the galaxy; however, often certain things could be developed much sooner when there is a strong need.

[6] Altshuller, Genrich, and Raphael Shapiro. *Psychology of Inventive Creativity*, Voprocy Psyhologii, no. 6, 1956, pp. 37-49. For an abridged English translation, see Altshuller, G.S. and R.B. Shapiro. *Izobretenia* (Journal for The Altshuller Institute for TRIZ Studies), Volume II, Autumn 2000.

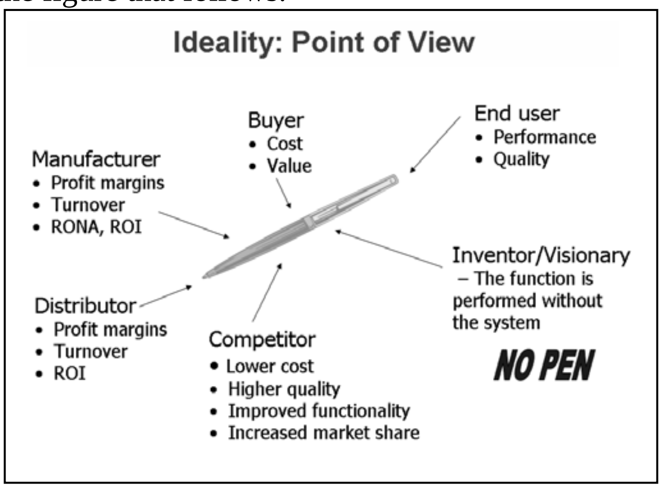
[7] Other possible definitions (translations): Ideal Ultimate Result, Ideal Ultimate Solution.

factors. Over the last several decades, the concepts of the ideal machine and the ideal final result have yielded a number of elegant and cost-effective solutions, however, there are no statistics regarding the success rate of these solutions in terms of successful implementation. Moreover, the extensive efforts related to the notion of ideality presented certain problems, in particular:

- Dependence of the ideal solution statement on point of view
- Lack of precise procedures for transitioning from an imaginable solution to an actual solution.

Let's consider each of the above in more detail.

As more and more practical problems were addressed, it became evident that the vision of an ideal solution differs according to the objectives of the problem solver, as shown in the figure that follows.



The most alarming situation occurs when the formula for the ideal system is applied to a final product; while the "no pen" formula is quite desirable for the pen user, it is unacceptable to the pen manufacturer, who would have no product to sell.

Moreover, the same solution might have a different degree of ideality in different situations, depending on the available resources. For example, a solution to a problem that requires welding might be nearly ideal for a company that has a welding process in place (equipment, trained operators, etc.) but far from ideal for a company that does not.

In earlier versions of ARIZ, the following steps were suggested in order to transition from the ideal to the real solution:

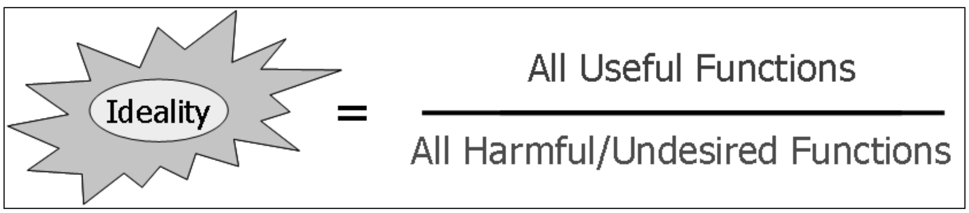
1. Envision the ideal solution
2. Identify an obstacle that prevents the ideal solution from being achieved
3. Identify specific (preferably physical) reasons why this obstacle exists
4. Identify changes by which the obstacle can be overcome

In later versions of ARIZ, a procedure for "stepping back" from the Ideal Final Result was introduced that included the following sub-steps:

1. Create a physical picture of the ideal solution
2. Imagine a tiny dismantling action applied to the ideal picture
3. Identify an action that can restore the ideal picture
4. Consider this restoring action as a means to realize the ideal solution

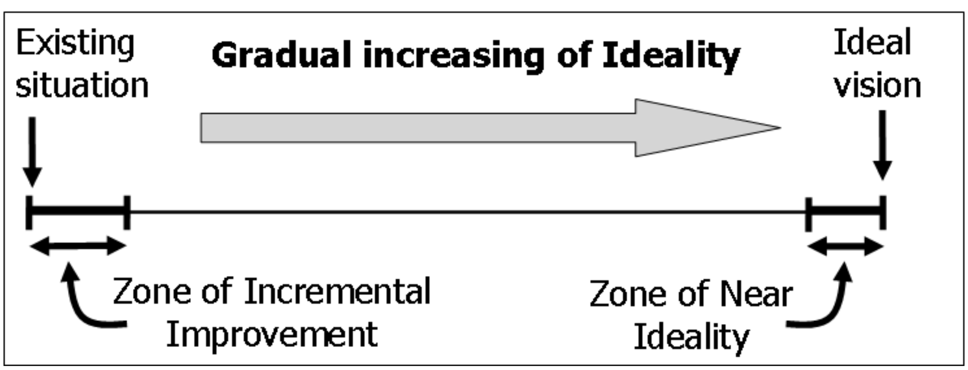
While both of these approaches were generally helpful, neither was rigorous enough to help different users obtain similar results.

In the late 1970s, Boris Zlotin transformed Altshuller's verbal description of an ideal system (no weight, size, dimensions, etc.) into the following formula:



This formula allows for the following derivatives:

- Altshuller's ideal machine can be regarded as the limit that is obtained when the denominator is driven to zero
- The formula itself connects two points in the evolution of a system: the existing situation and the final, desirable one (see the figure below)



While Altshuller's ideal vision facilitates a significant leap in thinking by breaking psychological barriers and providing other creative assistance, the above formula provides two ways that the ultimate ideal result can be approached in actuality. These are:

- Increasing the number and efficiency of useful functions
- Reducing the number and intensity of harmful functions[8]

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[8] See more detail in Zlotin, Boris and Alla Zusman. *Directed Evolution: Philosophy, Theory and Practice*. Ideation International Inc., 2001, page 41.

An important feature of the Directed Evolution approach as opposed to the classical TRIZ approach is its acceptance and absorption of valuable tools, instruments and approaches developed outside of TRIZ, such as Value Engineering, Quality Function Deployment, etc. These tools, when combined with the advanced understanding of ideality described above, become quite useful in the development of consummate systems.

Main aspects of developing consummate systems

The most significant aspects of product/process development in the informational era can be described as follows:

- Reliable prediction of future market needs and technological possibilities given the continuously increasing interconnections between various systems
- Increasing use of available modules rather than designing them “from scratch”
- Idealization

Let’s consider each aspect in more detail.

Reliably predicting future market needs and technological possibilities

The first scientific methods for technological forecasting were introduced in the mid-1950s.[9] These were based on the notion that a system’s past is the key to its future, and therefore, studying a system’s past can reveal certain trends that, when extended into the future, can predict the future of the system. These methods resulted in a number of successful short-term predictions; however, most long-term predictions failed, seriously discrediting these methods.

Today it is clear why these methods failed: Short-term evolution is more or less linear and therefore can be somewhat reliably extrapolated. On the contrary, long-term evolution involves non-linear events such as inflection points on the evolutionary S-curve (see below), making simple extrapolation inapplicable.

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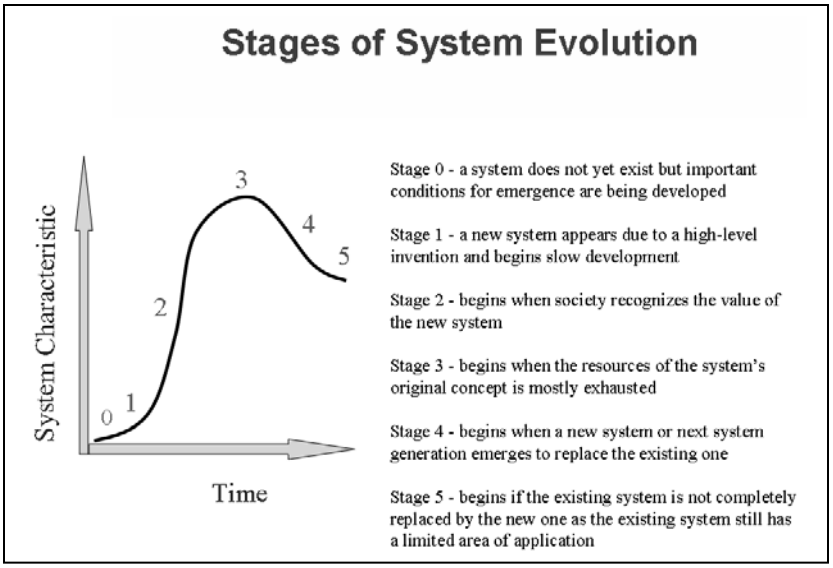
[9] Martino, Joseph Paul. *Technological Forecasting for Decision Making*, 2nd edition (North-Holland, 1983).



Another explanation is that short-term evolution depends in large part on the internal resources of a system, while long-term evolution depends more on the evolution of many other technological systems as well as the market as a whole.

The evolution of technology in the informational era is strongly dependent on the evolution of society, and vice versa: the increase and change in human needs continually drive the evolution of technology via market demands, while new scientific and technological discoveries offer new opportunities that shape these needs, which in turn push technological evolution further.[10] A countless number of these evolutionary spirals influence one another to create an environment of mutual dependence. For example, existing industries provide capital that can be used to launch new start-up technologies that boost long-established businesses. The evolution of contemporary technology spreads like a fire in a town made up of closely packed homes. Increased productivity in agriculture releases an abundant workforce to the cities; cheap labor combined with the growing demand for agricultural machines and technology stimulate the metallurgical, chemical, and transportation industries, which yield improved technologies that serve to further increase agricultural productivity. The growth of the transportation industry creates demands for better technologies and management; new management methods revolutionize the older industries, and so on. Traditional forecasting methods do not offer tools that allow us to foresee these complex changes.

It is even more difficult to consider the relationships between forecasting and its results: merely making a prediction and publicizing it can affect (either positively or negatively) the realization of one or another variant of the future. In addition, the fact that the short-term and long-term results of an action nearly always produce opposite results adds to the

[10] We call this evolving feedback spiral phenomenon Cause-Effect Co-evolution, or 2CE effect.

complexity of the task.[11] Indeed, as short-term results come closer to meeting expectations, long-term results often become more unexpected.

Given the above, we find ourselves in a vicious circle: to reliably predict the future of a specific system, one must first predict the future of human society as a whole, which can be done only by incorporating the predictions for the specific system. Even if this were possible (using multiple iterations, for example) it makes no practical sense to forecast the future of the entire world just to identify the next-generation air freshener or flash light.

According to TRIZ, within every difficult problem resides a contradiction that can often be resolved by applying the appropriate tools. In our case, for example, by applying the inventive principle ***preliminary action***[12] the following were suggested:

1. Developing and applying a system of evolutionary patterns that represent a ***generalized refined forecast or a concise description of the future.***[13] The patterns of evolution show the most probable future directions for a system that comply with the evolution of the most other systems.
2. Develop beforehand a comprehensive set of coordinated predictions (scenarios) of the evolution of the most important domains of human life (energy, health, housing, retail business, food, communication, transportation, etc.). These scenarios should be continuously undated and made available to all those involved in forecasting the evolution of systems of lesser rank. This makes it possible to coordinate numerous forecasts in different areas so that they can contribute to one another.

While the work described in the first direction has been in progress within TRIZ since the mid-1970s, the second direction, which requires the development of a bank of completed forecasts in different areas, is quite new. The most recent predecessor is the book by Daniel Burrus describing 24 futuristic technologies that will significantly impact human life.[14] At the same time, while the book addresses important enabling technologies that could be used in many different industries and areas of human activity, our approach seeks to build the most comprehensive futuristic pictures for these domains.

The following milestones in the development of this approach should be noted. Namely:

- The first course on Patterns of Technological Evolution developed by Boris Zlotin in 1975 and delivered in St. Petersburg's Evening TRIZ University focused primarily on the application of a limited number of patterns to various

[11] Fore example, cutting income taxes at first reduces the revenue and can create or increase the budget deficit. In longer term, though it can stimulate economy, increase the taxes base and eventually produce more revenue from the taxes.
[12] Altshuller, Genrich. TRIZ *Keys to Technical Innovation*. Technical Innovation Center, Worchester, MA, 2002.
[13] In the similar sense, a differential equation is a generalized description of a number of processes, sometimes quite different in nature. This general equation could be specified by introducing specific initial and boundary conditions and solved.
[14] Burrus, Daniel with Roger Gittines. *Technotrends*. HarperCollins Publishers, Inc. New York, 1993.

technological systems; the goal was to predict certain aspects in the evolution of these systems and to document the results. Other predictions followed later.

- Many TRIZ forecasting projects and, later, Directed Evolution projects, required that research be conducted in more general areas; for example, predicting the future of cleaning products cannot be reliably done without developing a vision for the future of housing; predicting the evolution of an automobile engine requires an understanding of the future of energy, etc. These general predictions were expanded and updated, eventually forming the foundation for a knowledge base called the Bank of Evolutionary Alternatives™.[15]

The Bank of Evolutionary Alternatives covers about 10 general domains and is utilized to increase the reliability of predictions for various systems within these general domains.

Increasing use of available modules rather than designing "from scratch"

To date, millions of various technologies and methods for providing various functions have been developed. As a result, it is often more cost effective to find a suitable existing technology and adapt or modify it (if necessary) than invent an entirely new system. And indeed, building new systems from existing modules is a main trend in contemporary design. In the past, this trend was seen only in simple parts such as nuts and bolts, followed by bearings, gears, etc. Today most designs are made using catalogs; for example, the designer of a new vacuum cleaner selects the appropriate motor, pump, filters, microchip, hoses, attachments, etc. from a catalog, while creatively addressing the new style, additional features (which might entail adding new parts or assemblies) and the integration of systems elements. Modular or catalog design allows for the maximized use of proven technologies and designs, and minimizes unexpected drawbacks and other unpleasant surprises that can surface as a result of excessive novelty.

The trend described above also explains the surprisingly low effectiveness in utilizing the TRIZ knowledge base of physical, chemical, geometric and other effects. Designers prefer to apply working modules rather then spend time exploring new effects, experimenting, prototyping, etc.

To the best of our knowledge, the first TRIZ group to recognize this new direction was the group of TRIZ practitioners led by Simon Litvin. In the late 1980s, this group began constructing and applying a guide of technological effects,[16] and later developed a method called functionally oriented design. The method is based on identifying a main functional need and then searching for the leading technology in the given area to find the most suitable prototype.[17]

[15] Zlotin, Boris and Alla Zusman. *Bank of Evolutionary Alternatives™*. Presented at TRIZCON 2004.

[16] Litvin, Simon, Alex Lubomirskiy. "Bank of technological effects." *Journal of TRIZ*, Volume 1-2,1990, page. 22 (In Russian).

[17] Litvin, Simon. "New TRIZ-based Tool – Function-Oriented Search." ETRIA Conference TRIZ Future 2004. November 2-5, 2004, Florence, Italy

For decades, this kind of search required the creation of special databases along with other considerable efforts. Recently, powerful search engines such as Google, Delphion-Thomson and others have made such tasks easier; but even the smartest search engines based on semantic analysis cannot help with the most difficult part: identify leading technologies. This requires extensive TRIZ analysis which can only be conducted by TRIZ professionals with substantial TRIZ experience.

Directed Evolution, on the other hand, offers a set of standard procedures that can help in the preliminary analysis prior to the search. In particular, these procedures include:

1. Conducting a limited search based on initial information with the goal of learning the specifics of a situation and identifying available resources, typical problems, etc.
2. Creating graphical cause-and-effect descriptions of the situation, and formulating a practically exhausting set of directions for innovative solutions using a special problem formulation technique.[18]
3. Analyzing the obtained directions, and then selecting the most promising ones for a detailed exploration using operators[19] that target an exhaustive set of potential solutions.
4. Analyzing and selecting a preliminary set of potential solutions, then formulating them in a more abstract (general) way; this allows for a broader search to identify areas in which analogous solutions have already been found and possibly implemented.
5. Conducting a patent search in the areas of interest, to reveal patents describing similar solutions. Using the search results to identify companies and inventors working in these areas.
6. Searching for existing systems and products in which these solutions have been implemented.
7. Revealing and solving problems that arise as a result of transferring the solution and adapting existing systems for utilization in the given area.

The following instruments are recommended for a more effective implementation of the modular approach:

Work content	**Instruments**
1. Revealing (or inventing) and verifying new needs and/or functions capable of satisfying certain needs	▪ Set of patterns, lines and trends of evolution of human needs and functions ▪ Bank of Evolutionary Alternatives

[18] *TRIZ in Progress*. Transactions of the Ideation Research Group. Ideation International Inc., 1999. pages 123-140.
[19] *TRIZ in Progress*. Transactions of the Ideation Research Group. Ideation International Inc., 1999, pages 114-122.

2. Searching for solutions and selecting suitable modules	▪ Inventive Problem Solving process ▪ Search based on a practically exhaustive set of obtained solutions
3. Integrating modules in the system to build a "monster system"[20]	▪ Step-by-step algorithm for creating a new system ▪ Technique for formulating and resolving contradictions ▪ Module coordination (matching) technique
4. Conducting an effective search for missing modules, or modules that are especially easy to adapt to the needs of a given system	Inverted approach to the search, including: ▪ Inventive problem solving targeting the best way to perform the given function ▪ Patent search for existing variants for realizing this function ▪ Search for a product (producer) that can provide a needed solution and enhancing or adapting it, if necessary.
5. System optimization	▪ Anticipatory Failure Determination (AFD)® ▪ Hybridization technique ▪ Idealization technique (see below)
6. Further system enhancement as new, more advanced modules, are introduced	Return to # 2, above.

Idealization[21]

Consummate systems

A consummate system can be characterized by the following features:

- The system is perfect within the context of a certain specific environment. When the latter comes to an end, the system gives way to the next-generation system.[22]

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[20] A "monster system" is an initial blunt-force attempt (often imaginary) to combine all modules necessary to perform the required function.

[21] The process of increasing a system's ideality defined earlier as a ratio of all useful functions, features and benefits versus all that must be paid for them, including various actual costs and non-tangible harmful effects associated with the performance of useful functions.

[22] For example, the Ford Model-T automobile would be unable to drive on today's freeways; at the same time it was perfect in the beginning of the 20th century, where unpaved roads provided a very important function: i.e., allowing farmers to deliver their produce to consumers from nearby towns without the use of a "middle man," enhancing the supply of food to consumers and increasing the quality of their lives. Later, during times of high unemployment, automobiles helped people find jobs by expanding the range of acceptable distance from work and allowing them to reside in remote areas where the cost of living was lower. The Kalashnikov machine gun is perfect for poorly trained soldiers and unsophisticated environments.

- The system meets mass, long-term customer needs, providing just what is necessary and no more.
- The system fully implements the possibilities defined by its principle of operation; it performs its function(s) with a minimal number of parts.
- The system's parts and other details are given the most attention, their performance is worked out as best as possible; the system has the highest reliability, minimal weight, energy and other types of waste, vibration, noise, wear, etc.
- The consummate system is never too specific, and rarely fills the lead position for a specific parameter (e.g., speed, load, precision, etc.), but is often the best in terms of lifetime, sales volume, customers affection, etc.
- The consummate system often provides super-effects – additional attractive benefits for the customer that were not foreseen by the inventors.
- In a certain fashion, the consummate system is close to biological systems in which the performance of an important function often depends on multiple sub-systems and their effective cooperation.[23]
- Sub-systems of the consummate system always share their resources; problems and contradictions that emerge in the evolution of one sub-system are resolved by utilizing resources of another sub-system or of the overall system.
- From the resources point of view, the consummate system has no spare resources; the resources were exploited to the utmost as the system was perfected, therefore, the system cannot be easily modified or improved without losing its consummate state. These systems are usually in service for a long time and are then simply replaced with the next generation system.

In the history of technological evolution, consummate systems typically emerge under the following conditions:

- Mass demand and production
- Fierce competition

American experience in the development of mass consumer products shows that with adequate effort and investment, almost any product can be made perfect or almost perfect (a multi-blade shaving razor, for example); however, the process of achieving perfection is very costly if carried out in the absence well-defined processes and effective tools.

In the mid-1900s, two main approaches were introduced that targeted system perfection:

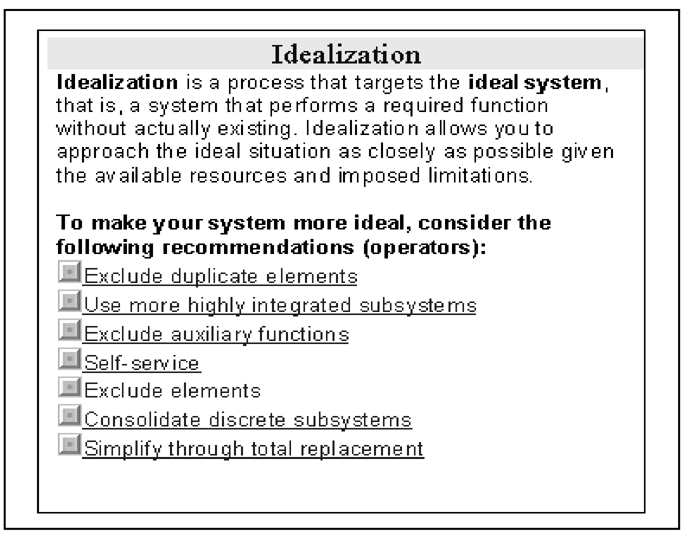
- Value Engineering, which focused mainly on cost reduction
- Quality Engineering, which focused on increasing products/process quality

[23] For example, the safety of the old Volkswagen and the reliability of the Kalashnikov machine gun are determined by overall design rather than by a specific part like a bumper, etc.

Traditionally, cost and quality are in conflict (contradictory): the typical means for cost reduction can negatively impact quality, and vise versa. However, both of the above approaches were initially quite successful, especially with products that originated without much consideration of cost and/or quality (producer's market) and thus possessed significant resources for improvement. The marketing revolution that took place between 1955 and 1985 shifted market domination from producer to consumer. Where earlier consumers bought whatever they could find without much regard for a product's excessive weight, low quality, etc., they could now choose better products, pushing producers toward continuous improvement. Unfortunately, each cycle of cost reduction or quality improvement depleted the inherent resources available in a system, sharpening the contradiction between them and increasing the competition for resources. As a result, most contemporary products have had the resources "squeezed out" of them[24] *and cannot be significantly improved without resolving contradictions and applying other TRIZ-based methods for increasing a system's ideality.*

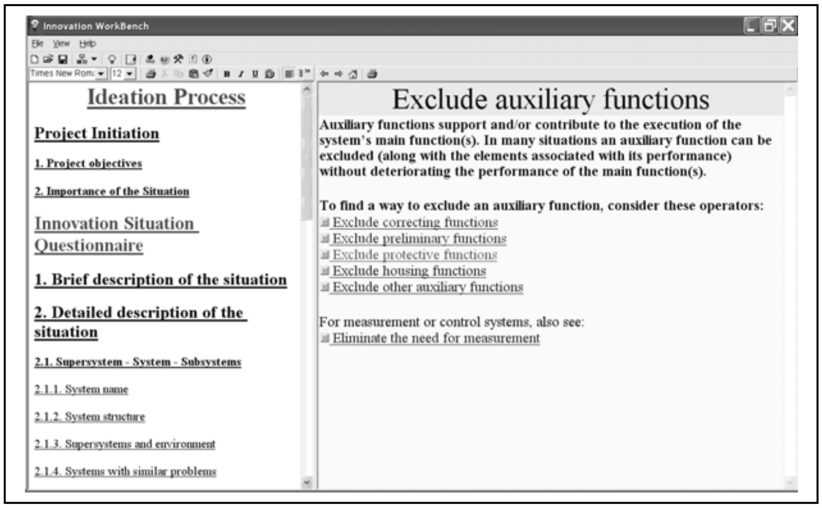
Ideation Operators for Idealization

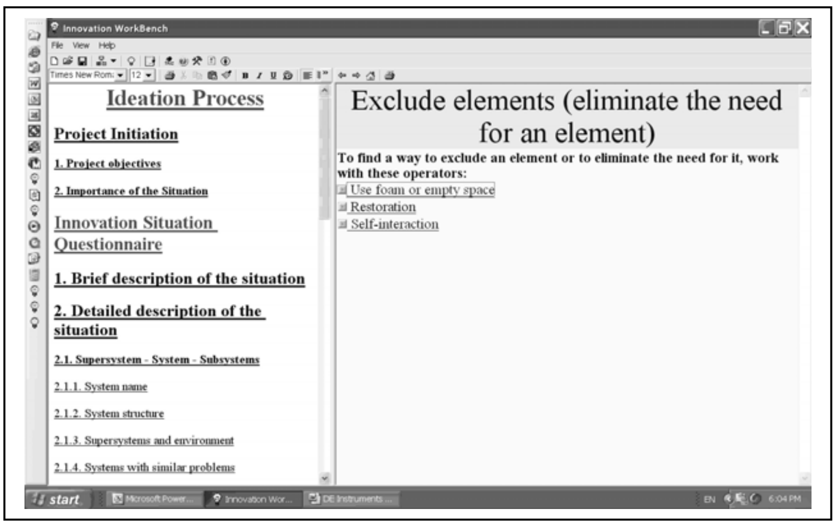
The first attempts to successfully address the cost/quality challenge using TRIZ instruments were made in the late 1970s and early 1980s.[25] Later, this work resulted in the creation of Value/Quality Engineering, which summarized all effective techniques and allowed for ***simultaneously*** reducing cost *and* increasing quality.[26] In the early 1990s, this approach resulted in the development of a knowledge base that included a specialized set of operators[27] dedicated to system idealization; these operators integrated all relevant TRIZ principles, standard solutions (such as self-service, use of voids, foam, etc.) and newly developed operators, such as the following:



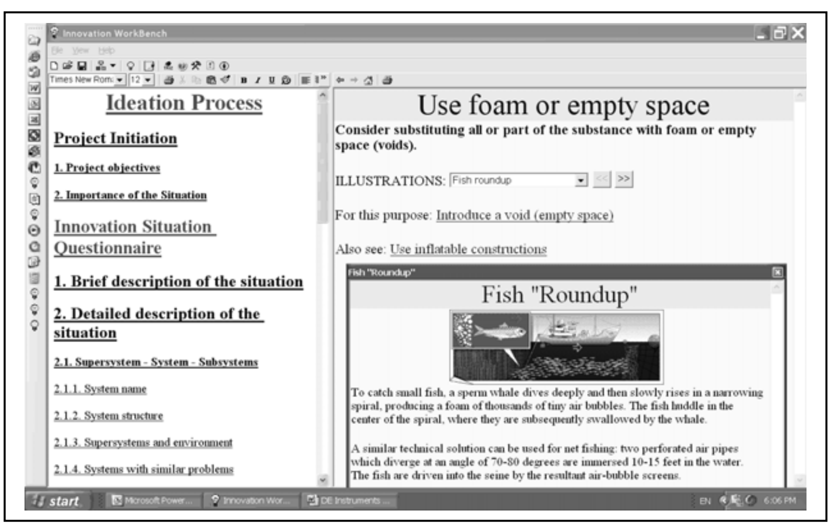
[24] For example, in the 1950s, to increase an automobile's electrical power, a more powerful alternator could be placed under the hood – there was plenty of empty space. Today this task would require completely redesigning the whole under-hood area, at enormous cost.
[25] Boris Zlotin's experience in integrating TRIZ and Value Engineering techniques at the Electrosila company (St. Petersburg, Russia).
[26] *TRIZ in Progress*. Transactions of the Ideation Research Group. Ideation International Inc., 1999, pages 158-173.
[27] *TRIZ in Progress*. Transactions of the Ideation Research Group. Ideation International Inc., 1999, pages 114-122.

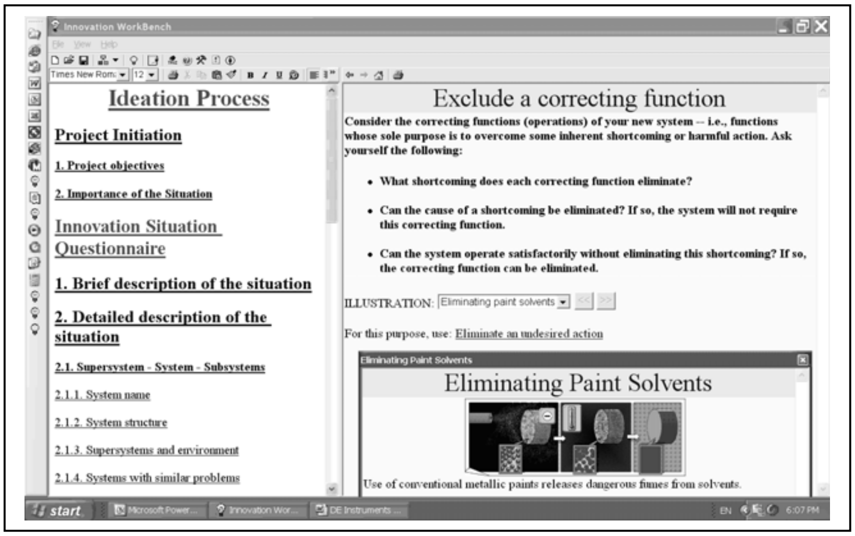
Certain items from the above menu represent a sub-group of operators, for example:





Each operator consists of a recommendation and one or more illustrations, for example:





Altogether, these specialized operators, which include additional references to other relevant operators, checklists of possible resources, and other useful links, form quite a comprehensive system, which is available to users of the Innovation WorkBench® software.

A simplified manual process for the idealization of simple parts or small assemblies, along with an example, can be found in the appendix.

Division of labor in the development of contemporary systems

Prior to the industrial era, creating a new product was a one-man process; an architect would specify the customer’s primary requirements, develop the architecture, design and manage the project’s logistics, etc. Craftsmen and other providers of unique products would work in a similar fashion.

The industrial era extended the division-of-labor principle into the new product development to create new professions: inventors, designers, production engineers, quality personnel, etc. (of course, in certain cases some of these professions can still be attributed to one individual).

The informational era should – and is – spawning additional professions:

- *Director of evolution* – an individual who understands future needs and technological opportunities, and is capable of formulating the “evolutionary request” for a product/process
- *Inventors* able to invent new products and processes to satisfy this request
- *System integrators* who can conduct the search for necessary known “ingredients” and use them to assemble a system that can provide the required function(s). Typically first results in a “monster system” that is far from being optimal, let alone consummate.

- *Idealizers* who specialize in converting a "beast" into a "beauty," possessing all the necessary skills for system idealization.

Conclusions

1. TRIZ has far outgrown its name, confusing the market as to its real potential: problem solving is only a small part of what TRIZ professionals can do (similarly, mathematics is much more than solving equations). TRIZ professionals have known this for quite a while and have had a number of discussions on the topic (without noticeable effect, however).
2. In the current information era, the growing need exists for a new science and, more importantly, practical methods for the purposeful management and control of the evolution of various systems; this science can, in our opinion, soon become a core science. We at Ideation call it Directed Evolution; the eventual name might be different. The most important thing is that this science has already emerged and will grow, with or without us. Now is the time to do something about it if we want TRIZ – Altshuller's creation – to continue to advance in the 21st century and the informational era.
3. This new science must encompass effective practical tools for the development of consummate systems that maximize the ideality ratio: maximum benefits over minimal overall costs and intangible negative effects.

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11. Zlotin, Boris and Alla Zusman. *Bank of Evolutionary Alternatives*™. Presented at TRIZCON 2004.

APPENDIX

Suggested Idealization Process and Example[28]

1. Become familiar with the object

- Have or make a good (preferably 3-D) picture of the given part or assembly.
- Work with the actual system, if it is not too large. Have tools on hand for disassembling the object if necessary.
- Tour the manufacturing facilities if possible, or obtain a movie or set of pictures that illustrate the production process.

2. Disassemble/dissect the object

- Disassemble/dissect (either mentally or, if possible, actually) the object into elements that are simple in shape or manufactured via a simple operation.
- Give a simple name to the each element (imagine that you are explaining the object design to a teenager).
- Name the function of the each element using simple words (imagine that you must explain to the teenager why each element is necessary).

3. Define the useful functions (main, auxiliary, secondary)

- Each object or object element is created to perform a certain function(s) to satisfy the requirements of the object's super-system (a system of higher rank that includes the given object/element as a part). This function is defined as the main function of the object/element. For example, the main function of a telephone key is to dial the number.
- The performance of a main function usually requires auxiliary functions that contribute to it. Typical auxiliary functions are those that provide integrity to the part, protect it from environmental impact, supply and transfer energy, connect it with other elements in the same system (super-system), and so on. For example, an auxiliary function of a telephone key is returning it to its original position after it is released.
- All functions other than the main and auxiliary functions can be defined as secondary (additional) functions. Typically, secondary functions provide additional benefits, such as improved convenience, style, etc. Secondary functions for the telephone key include color, a concave shape fitted to the shape of a finger, etc.

4. Define the harmful and/or unnecessary functions

- Harmful functions include all "costs" associated with the given element, including various negative effects (sharp edges, noise, breakage, etc.) and undesired parameters (weight, dimensions, etc.).
- Unnecessary functions are auxiliary functions that do not actually contribute to the performance of the main function and can therefore be spared. Secondary functions that

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[28] The process below can be carried out manually or with software support.

provide no benefit (or provide questionable benefits) can also qualify as unnecessary. Typical unnecessary functions might be:

- Redundant or duplicate functions
- Excessive mechanical strength, accuracy, fixtures, tuning, etc.
- Elements that performed useful functions that became unnecessary due to product modifications or other changes.

5. Build cause-and-effect diagrams

The cause-effect diagrams[29] should reflect all relationships between various elements, and show how the elements and their relationships contribute to the main function (i.e., act as useful functions) or interfere with it (act as harmful functions). Functions and elements that do not contribute to the main function and provide no other benefit are unnecessary.

6. Build the ideal model of a part or small assembly

- Select only the main elements of the system (those that provide the main functions).
- Create a picture that combines the main elements in the simplest way. Simplicity is the key: the picture can look more like a symbolic representation than a real part.

7. Build the real system based on the ideal model

Once the ideal model is created, convert it into a workable part or assembly as follows:

- Add the auxiliary elements necessary to ensure real functionality
- For each added element consider several alternatives, and define the pluses and minuses of each.
- Consider possible combinations from available alternatives to make sure you have selected the most cost-effective one.

8. Document the solution(s)

Document all obtained ideas (i.e., all possible designs), keeping in mind the following:

- Each idea/design/concept should be briefly described, both verbally and graphically. Be brief enough to ensure an uninterrupted creative environment, but include enough detail to enable later evaluation.
- Be sure to capture all ideas

9. Express evaluation of the obtained idea(s)

- Ensure that the new design provides all necessary main functions. If not, consider absent functions as so-called consequent problems.
- Determine whether the new design can create harmful or unnecessary functions. If so, consider these as consequent problems.
- Determine whether the new design provides additional useful functions. If so, consider ways they might be strengthened and utilized.

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[29] Can be built manually (as described in Zlotin and Zusman's *Directed Evolution*) or with the use of the Problem Formulator module (Innovation WorkBench® or Knowledge Wizard® software).

10. Next idealization cycle

- Imagine that the solution you have found cannot be utilized.
- Return to step 7 and look for another solution, keeping in mind the following:
  - Typically, the first solution is not the best possible solution.
  - If at least one solution has been found, other solutions are possible based on the utilization of other resources.

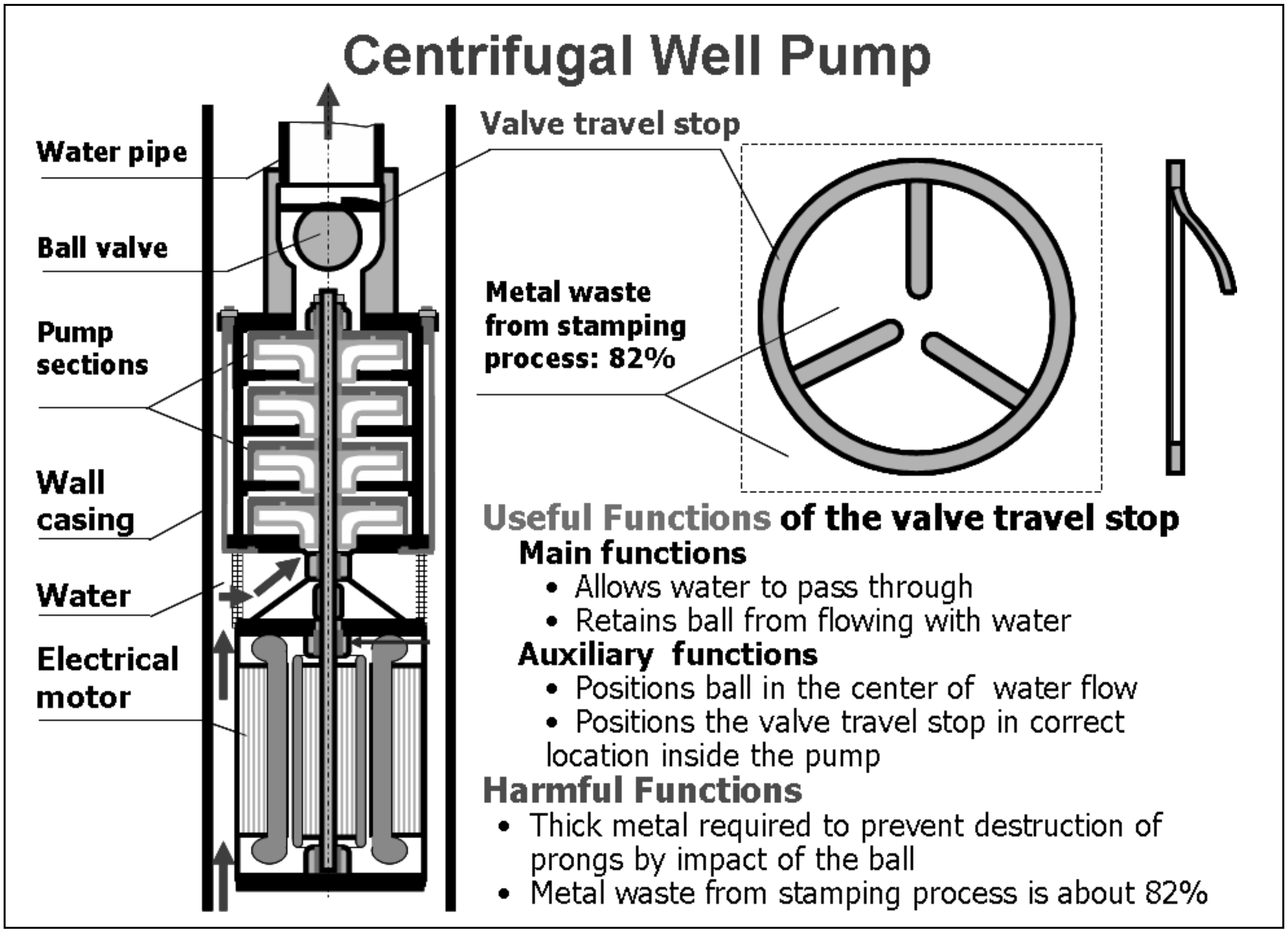
11. Hybridization

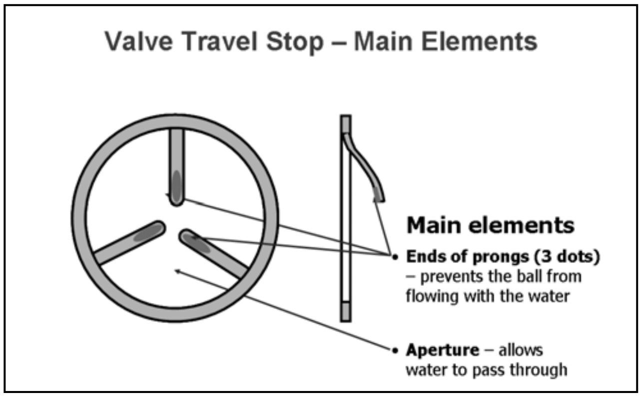
Try to hybridize the obtained solutions and identify the most cost-effective combination.

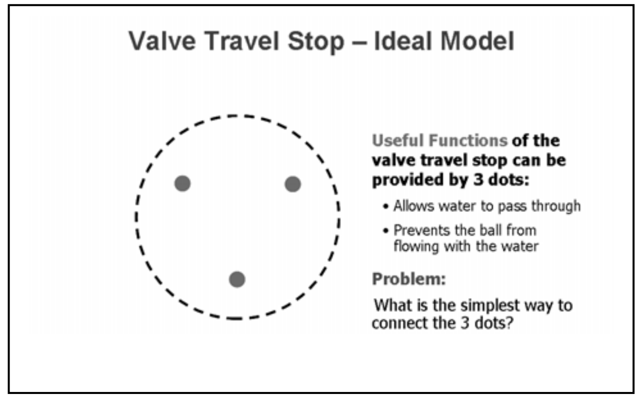
12. Express Failure Prediction on the obtained solution(s)

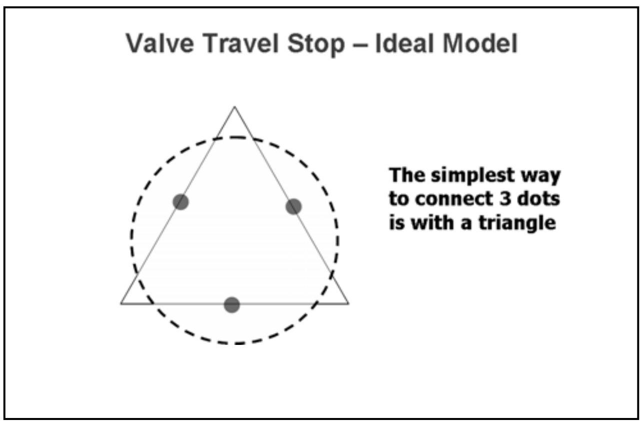
- Reveal potential problems associated with the obtained solution
- Formulate consequent tasks and resolve them

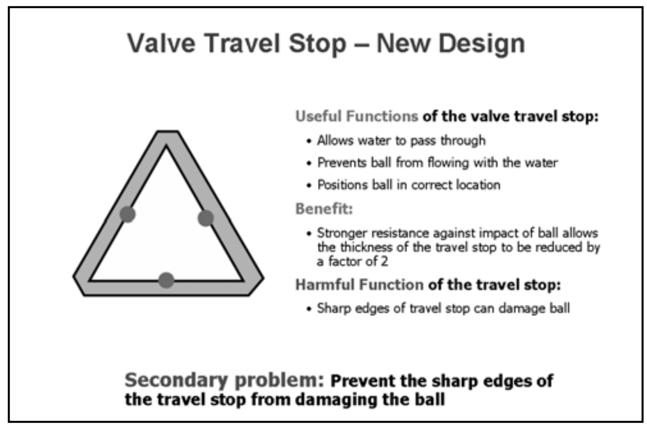
Illustration

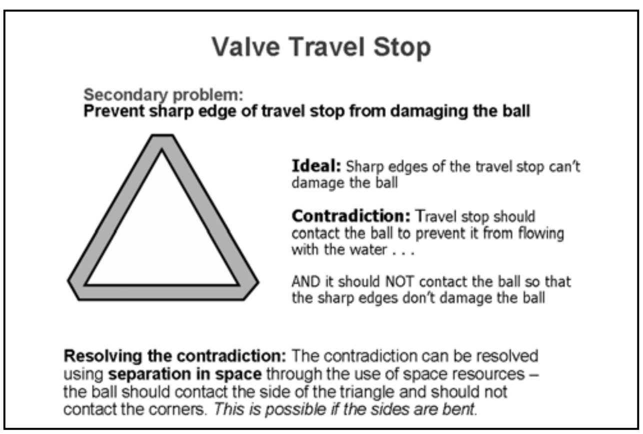


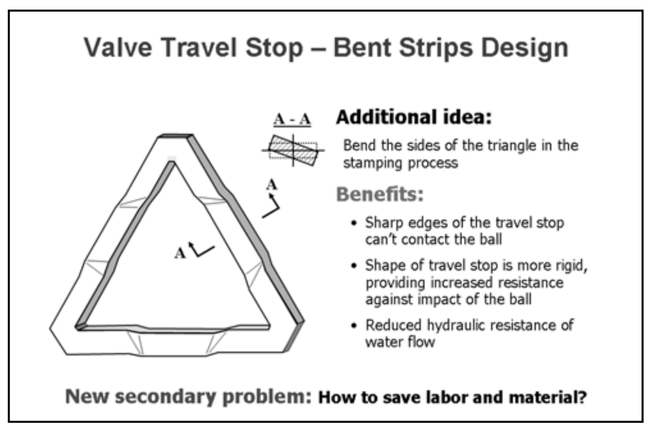

Valve Travel Stop – Main Elements
Main elements
Ends of prongs (3 dots) – prevents the ball from flowing with the water
Aperture – allows water to pass through

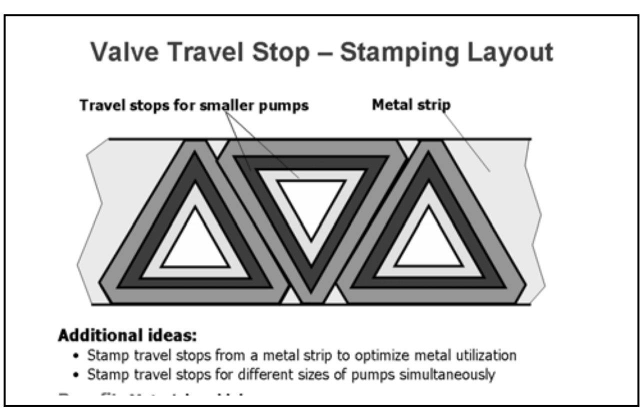

Valve Travel Stop – Ideal Model
Useful Functions of the valve travel stop can be provided by 3 dots:
• Allows water to pass through
• Prevents the ball from flowing with the water
Problem:
What is the simplest way to connect the 3 dots?

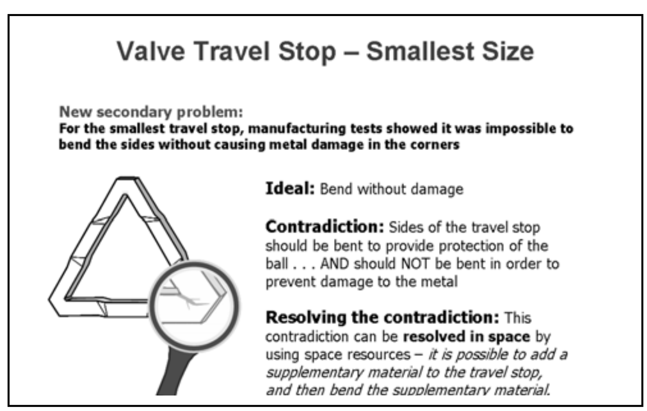

Valve Travel Stop – Ideal Model
The simplest way to connect 3 dots is with a triangle


Valve Travel Stop – New Design
Useful Functions of the valve travel stop:
• Allows water to pass through
• Prevents ball from flowing with the water
• Positions ball in correct location
Benefit:
• Stronger resistance against impact of ball allows the thickness of the travel stop to be reduced by a factor of 2
Harmful Function of the travel stop:
• Sharp edges of travel stop can damage ball
Secondary problem: Prevent the sharp edges of the travel stop from damaging the ball

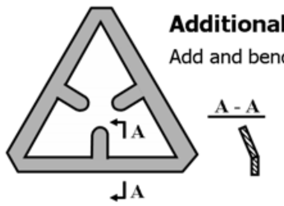

Valve Travel Stop
Secondary problem:
Prevent sharp edge of travel stop from damaging the ball
Ideal: Sharp edges of the travel stop can't damage the ball
Contradiction: Travel stop should contact the ball to prevent it from flowing with the water . . .
AND it should NOT contact the ball so that the sharp edges don't damage the ball
Resolving the contradiction: The contradiction can be resolved using separation in space through the use of space resources – the ball should contact the side of the triangle and should not contact the corners. This is possible if the sides are bent.


Valve Travel Stop – Bent Strips Design
A - A
A
A
Additional idea:
Bend the sides of the triangle in the stamping process
Benefits:
• Sharp edges of the travel stop can't contact the ball
• Shape of travel stop is more rigid, providing increased resistance against impact of the ball
• Reduced hydraulic resistance of water flow
New secondary problem: How to save labor and material?


Valve Travel Stop – Stamping Layout
Travel stops for smaller pumps
Metal strip
Additional ideas:
• Stamp travel stops from a metal strip to optimize metal utilization
• Stamp travel stops for different sizes of pumps simultaneously


Valve Travel Stop – Smallest Size
New secondary problem:
For the smallest travel stop, manufacturing tests showed it was impossible to bend the sides without causing metal damage in the corners
Ideal: Bend without damage
Contradiction: Sides of the travel stop should be bent to provide protection of the ball . . . AND should NOT be bent in order to prevent damage to the metal
Resolving the contradiction: This contradiction can be resolved in space by using space resources – it is possible to add a supplementary material to the travel stop, and then bend the supplementary material.

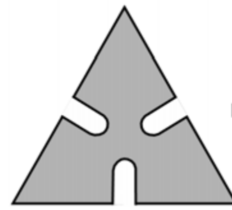
Valve Travel Stop – Smallest Size



Additional idea:

Add and bend prongs as needed

Valve Travel Stop – Stamping Waste



New secondary problem:

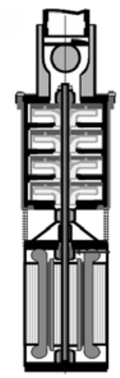
How can the waste be utilized?

Valve Travel Stop – Using the Waste

Additional idea:

Produce a furniture hook from the waste

Centrifugal Well Pump Idealization



During three years a group consisting of three TRIZ specialists and three technicians have been working with a Centrifugal Well Pump. The work included:

- Directed Evolution of pumps resulting in obtaining a set of promising directions in building the next generation of pumps.
- Anticipatory Failure Determination (AFD™) for the pumps that allowed to unveil over 20 reasons for deterioration of reliability and durability of pumps.
- TRIZ based Cost Reduction (Idealization)

Over 200 of various technological problems related to design and manufacturing process have been addressed resulting in significant quality improvement and production cost reduction.