Toolkit
Using Inventions in the Public Domain

Tool 13
TRIZ

WIPO

Tool 13: TRIZ

In this document we describe a tool for brainstorming solutions for conflicts between design specifications. These conflicts are often called contradictions, because improving performance on one specification inhibits or contradicts the ability to improve performance on the other specification, and vice versa. The TRIZ tool provides a version of the TRIZ problem-solving method developed by Genrikh Altshuller based on an analysis of patterns of invention in the global patent literature.

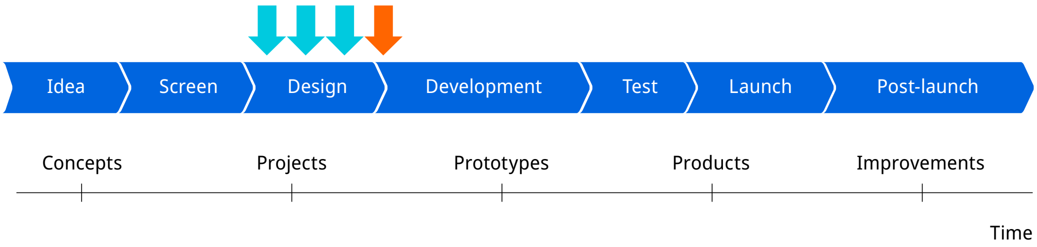
What is TRIZ?

TRIZ is an acronym for the Russian name for the methodology that will be described here. In English it is often referred to as the "Theory of Innovative Problem Solving." TRIZ is useful in two situations. The first is when you get stuck and cannot come up with a design that provides a competitive advantage on all the metrics important to customers and end-users. TRIZ helps you brainstorm non-intuitive solutions. The second is when you have an acceptable design but are reviewing it to see if there are ways to improve it. Using TRIZ can suggest alternative solutions which may be better at improving performance on multiple metrics of interest. An example is a cell phone needing a longer-life battery to be attractive to buyers and end-users. If solving this issue means having a heavier, larger and more expensive battery, that probably makes the phone less desirable to those people. Before accepting this impact mismatch as a given, it makes sense to look for alternative solutions.

TRIZ begins by identifying whether any of its 39 features that can give rise to contradictory elements exist in the design choice for your product or service. After the contradictions in the design are identified, TRIZ then requires the examination of 40 principles that have been successfully used to resolve such contradictions, to see if any suggested solutions to this contradiction or set of contradictions exist. A principle that could be used to solve the cell phone problem is: "Parameter changes: change state, concentration, flexibility." Many currently sold smartphones turn off various applications when they are not in use, reducing the draw on the battery and thus enabling longer battery life.

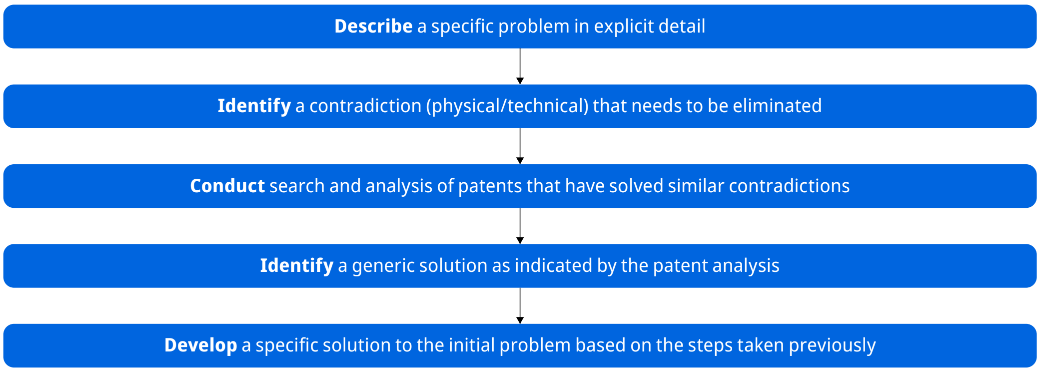
Because TRIZ is a tool for getting unstuck and brainstorming design alternatives, it can be used throughout the Design stage as needed. This is indicated by the multiple blue arrows in Figure 1. The orange arrow in Figure 1 indicates its use during final design review right before the gate between the Design and the Development stages.

Figure 1: **Stages and gates. The blue arrows show that the TRIZ tool can be used, as needed, anywhere in the design process. The orange arrow shows that the TRIZ tool should be used during final design review, right before entering the Development stage.**



This tool supports Module III "Integrating public domain knowledge into product development processes," section 9 "Design," sub-section 9.2 "Solution of a technical problem through TRIZ" in the WIPO publication Using Inventions in the Public Domain: A Guide for Inventors and Entrepreneurs (2020). The WIPO publication shows a five-step method for doing a TRIZ analysis, shown in Figure 2. This five-step approach is followed in this discussion of how to use the TRIZ tool.

Figure 2: **Steps involved in using the TRIZ methodology from Using Inventions in the Public Domain: A Guide for Inventors and Entrepreneurs (2020), Figure 15.**



How do you enter data in the TRIZ tool?

As explained, the TRIZ tool is designed to follow the five-step procedure for using the TRIZ methodology outlined in Using Inventions in the Public Domain: A Guide for Inventors and Entrepreneurs (2020).

Step 1: Describe a specific problem in explicit detail

Begin by examining your results from the Competitive Advantage tool. Examine the criteria that buyers and end-users will use to evaluate your product or service. It also helps to read the interviews and analysis done in connection with the Voice of the Customer tool, and the factors and conclusions developed when using the SWOT Analysis tool.

Figure 3 shows an extract from the "Inputs" tab of the Competitive Advantage workbook using the biofuels example.

Figure 3: **Key criteria for end-users and buyers, from the "Inputs" tab of the Competitive Advantage workbook using the biofuels example.**

Closeness of good on a scale of 1 to 10

Desired core benefits and features (customer requirements)	Ease of use	Efficiency	Applicability	Environment-friendly	Affordability	Scalability	Delivery anywhere	Average
Our product	10	7	8	10	10	9	8	8.9
OWS	8	7	7	7	7	8	5	7.0
Anaergia, Inc.	8	8	9	6	7	6	4	6.9
Fiberight, LLC	8	8	8	7	5	7	1	6.3
Thomas Asher	6	7	7	6	8	5	3	6.0
BriJen Biotech, LLC	7	7	7	7	6	6	6	6.6
Aarhus University	7	7	5	6	7	3	7	6.0
WSU	8	7	6	6	7	8	8	7.1
U. Patras	6	6	6	6	7	9	10	7.1

Next, look at how your design seeks to fulfill those criteria, meets the requirements of end-users and buyers, and satisfies your 4Ps (product, price, place and promotion). If there are contradictions in the ways you do that, deploy the TRIZ tool. You can also use the TRIZ tool to check the rest of your design for possible improvements.

Consider the biofuels example, which requires a design for processing biomass to use in the mini-refinery. Suppose your design for the pre-processor is a single-pass approach which has two stations – one that chips and shreds, and one that grinds and mulches. These stations pre-process the crop waste before it is placed in the vat for the microorganisms to digest. A single-pass approach means once the biomass is inserted, it moves through these stations in sequential order. In the current single-pass approach, everything (regardless of size) will be cut. After passing through these stations, the mulch slurry passes through a gate which spreads it out on the conveyor belt. A set of optical sensors look at the slurry after this gate to confirm that the quality of the slurry is appropriately sized for efficient digestion. If it is not, the biomass conveyor backs up and the biomass is ground and/or mulched further.

During concurrent engineering, some of your users express the desire to load brush from shrubs and woody weeds, and have it converted to fuel. Loading brush is desirable because, according to them, it gets mixed in with crop waste during harvest, and it is time-consuming to separate it. The brush has thicker stems and branches than the crop waste. At present, large biomass such as brush cannot be loaded because it will not fit in the hopper, which is designed to prevent clogging. However, redesigning the hopper is not a big problem.

Adding brush requires a new station – one that cuts the stems and branches into sizes that can be chipped. With the addition of this new station, however, the pre-processor requires significantly more energy, which decreases energy efficiency. It also raises concerns about clogging due to the size distribution of the cut biomass exiting the early stations. You could add another set of sensors at the output end of each station, but you are concerned that too many pieces of biomass with different textures and composition could overload the sensor by masking pieces which are too large but are hidden behind the ones closer to the sensor. On the other hand, it is not desirable to slow down the volume of material moving through the pre-processor, as it would take too long to fill the vat.

The easiest solution is to have a separate unit for cutting that feed into the original pre-processor. Another easy solution is to require the user to cut the brush to the right size using other tools. Unfortunately, either of these solutions mean the overall system is less efficient in terms of labor required. If you add a station, the mini-refinery is less energy-efficient although the problem of labor efficiency is eliminated. Alternatively, you can leave everything as it is and not process brush, but that contradicts having a mini-refinery that is applicable to the widest range of possible types of biomass waste. How can you redesign the pre-processor? What might that look like? These are questions you can use the TRIZ tool to help answer.

Step 2: Identify a contradiction that needs to be eliminated

TRIZ breaks down the potentially conflicting requirements into one or more contradictions on specific metrics. The first tab of the TRIZ workbook provides a TRIZ contradiction matrix populated with the 39 features that can give rise to contradictory elements in a design. Each of these 39 features can operate as an improving feature or a worsening feature, and they are arranged in a matrix format that allows you to consider interactions between features.

Begin brainstorming solutions to the conflict by scanning down the “Improving feature” list in the second column of the “Contradictions matrix” tab of the TRIZ workbook. Consider which, if any, “Improving feature” may apply to your problem. When you see a factor that may apply to your current design solution, determine if there is a contradicting metric that would apply to any of the other requirements in the “Worsening feature” columns starting on the third column. If there is, describe the contradiction in the cell where they intersect.

For help with selecting features in the TRIZ contradiction matrix, you can consult online publications that provide explanations of the 39 features and the 40 principles of TRIZ, and in some cases show how they apply in specific technology areas.

Figure 4 shows the “Contradiction matrix” tab for the biofuels example workbook. (By opening the TRIZ workbook using the biofuels example on your own computer, the spreadsheet will be easier to read.)

Two types of contradictions are identified: a contradiction between a) increasing the range of biomass you can handle, and b) increasing energy efficiency; and a contradiction between c) the quality of the material exiting the station given the accuracy of the measurement that ensures it is ready for the next stage, and d) the volume of material moving through the pre-processor. For one contradiction related to biomass quality and range problems, the improving feature called “Quantity of substance” (improving feature number 26) and the worsening feature called “Device complexity” (worsening feature number 36) were selected and the specifics of the contradiction are described at the intersection of the two in cell AL29 as “Too many moving parts as each cuts or grinds within limited size parameters.” Another contradiction is described in cell U29 at the intersection of the improving feature “Quantity of substance” (improving feature number 26) and the worsening feature “Use of energy by moving object” (worsening feature number 19). Another contraction is described in cell W29 at the intersection of the improving feature “Quantity of substance” (improving feature number 26) and the worsening feature “Power” (worsening feature number 21).

Figure 4: An extract from the "Contradiction matrix" tab of the TRIZ workbook using the biofuels example. Note that the conflict between the quality of the substance and energy efficiency shows up in one improving feature (no. 26 "Quantity of substance") and three worsening features (no. 19 "Use of energy by moving object," no. 21 "Power" and no. 36 "Device complexity"). For example, improving the "Quantity of substance" by adding brush to the biomass feed in the pre-processor has caused the worsening of feature no. 36 "Device complexity."

TRIZ contradiction matrix

	Worsening feature / Improving feature	Temperature	Illumination intensity	Use of energy by moving object	Use of energy by stationary object	Power	Loss of energy	Loss of substance	Loss of information	Loss of time	Quantity of substance	Reliability	Measurement accuracy	Manufacturing precision	Object-affected harmful factors	Object-generated harmful factors	Ease of manufacture	Ease of operation	Ease of repair	Adaptability or versatility	Device complexity	Difficulty of detecting and measuring	Extent of automation	Productivity
		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
24	Loss of information																							
25	Loss of time																							
26	Quantity of substance			The better the preprocessing, the more energy-consuming blades, shredders, and grinders are used.		To make biomass easier for organisms to digest, blades, mashers, or high-tech alternatives are required. Higher quality mashing reduces production time for fuel in the vat but necessitates more complex machinery, which increases power consumption and cost.															Too many moving parts are involved, as each cuts or grinds within limited size parameters.			
27	Reliability																							

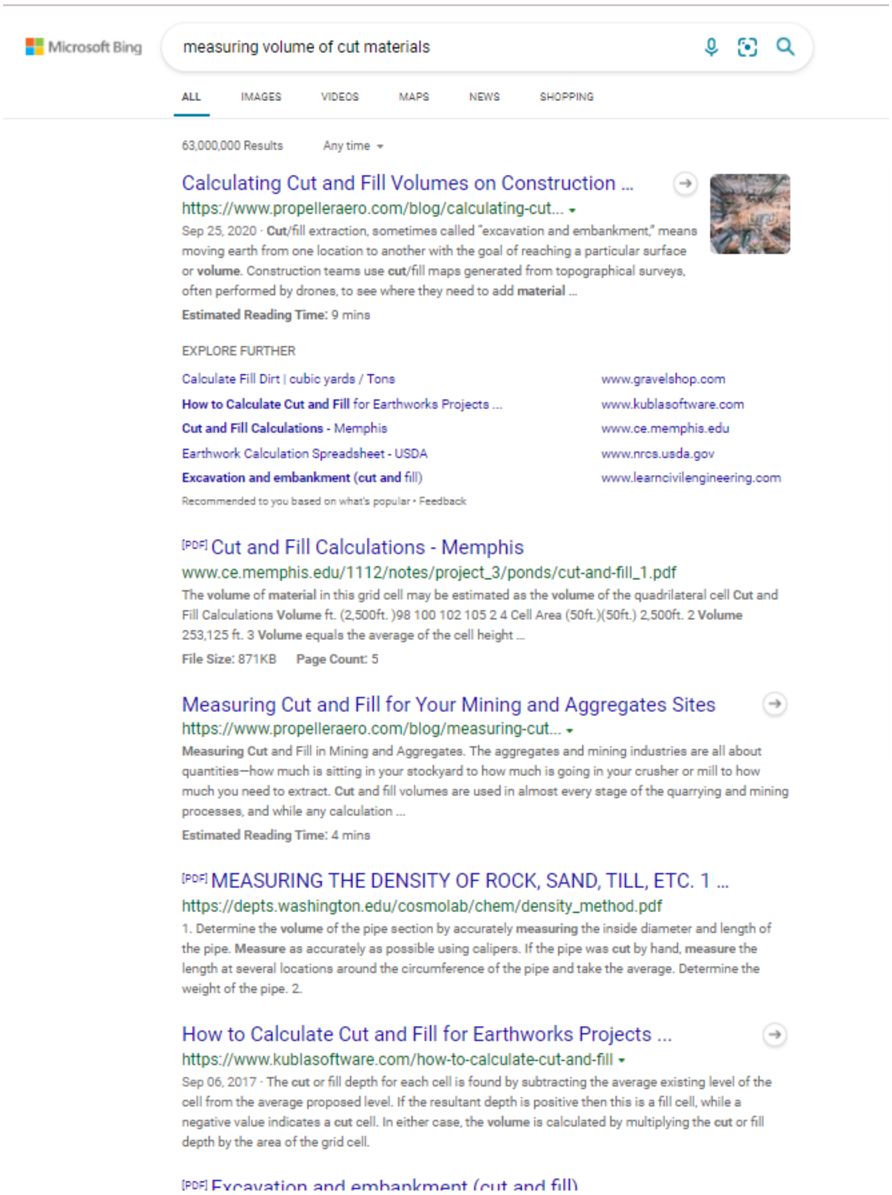
It is not necessary to explore all contradictions on the same "run" of the TRIZ tool. You can conduct multiple runs in order to explore one contradiction at a time. To do that, simply put the cursor on the tab and right-click so you can copy that tab. Then rename the tabs so you know which contradiction each addresses.

Step 3: Conduct a search of technical solutions that have solved similar contradictions

Compared to a traditional TRIZ approach, which relies only on the patent literature, in the age of the internet you can search a wider variety of sources. Enter your problem in a search engine, a searchable patent database, a searchable refereed literature database, or other places where solutions might be found. Examine the hits for possible analogous problems.

Figure 5 illustrates the use of web research for "measuring volume of cut materials" to address contradictions related to processing biomass for the mini-refinery in the biofuels example.

Figure 5: **To find information that may be useful for the biofuels example, the search string “measuring volume of cut materials” was entered in a web search engine.**



After the results from the search shown in Figure 5 are reviewed, suppose the hit relating to mining catches your attention. In mining, bulky material is also cut and ground or crushed to smaller sizes. This suggests mining operations may face an equivalent problem, so a solution from mining may be applicable to one of the contradictions in the biomass processing fact pattern for the mini-refinery in the biofuels example. Further searching reveals that digital imaging processing is a solution to the equivalent problem in mining. One solution is the Split-Desktop® software, which was originally developed at the University of Arizona and is licensed to Split Engineering, LLC (www.spliteng.com), and which is used to determine sizes of fragments that are moving along a fully automatic and continuously operating conveyor belt. The article referenced in Figure 6 describes how the software does this and discusses its accuracy and sources of error.

Figure 6: **This screenshot of a web search result suggests that a possible solution can be found in a digital imaging processing approach for mining, and provides a link to an article that could provide detailed information.**

Step 4: Identify a generic solution

If a solution has not been found yet, the next step is to open the “Solution principles” tab of the TRIZ workbook. Examine if any of the 40 TRIZ inventive principles listed in the second column might apply. These TRIZ inventive principles are a standardized list of known solution principles that can trigger you to think about whether any of them would lead to a solution to address a contradiction. As before, you can copy this tab to explore various contradictions and their potential solutions separately.

Using these solution principles as a brainstorming tool, see if any of them might help. If a solution principle might apply, enter a comment about how it could do so in the “Useful” column for that principle (third column). Make an entry for each principle that might apply, with comments such as possible techniques suggested by applying this principle, or strategic questions related to applying that principle. If a solution principle does not seem likely to help, put an “X” in the “Not useful” column for that principle (fourth column). You can include comments in the “Not useful” column for a solution principle, if you want to remember why you reached that conclusion.

Figure 7 illustrates the use of the “Solution principles” tab to find a solution that addresses the contradiction described in the biofuels example at cell AL29 of the TRIZ contradiction matrix, between “Quantity of substance” and “Device complexity” for biomass processing.

Previously, potential design problems related to biomass processing were identified based on information gained from using other tools such as Voice of the Customer, Competitive Advantage and SWOT Analysis. Then, the TRIZ contradiction matrix was used to find design contradictions, including the contradiction being discussed here. As shown in the “Solution principles” tab reproduced in Figure 7, some of the TRIZ inventive principles were useful for triggering ideas about potential solutions to address this contradiction for the biofuels mini-refinery design, as shown in remarks in cells C5, C6, C15, C16 and C18.

To validate the feasibility of any of these potential solutions, search for that solution on the web, using the approach described in Step 3. You could carry out a general web search using a search engine, a search of the patent literature, a search of refereed literature, a trade press or advertising search, and/or a search of any other suitable sources of information.

Figure 7: **The "Solution principles" tab of the TRIZ workbook using the biofuels example, addressing the contradiction between "Quantity of substance" and "Device complexity."**

TRIZ inventive principles

		Useful	Not useful
1	Segmentation: divide into parts, make easy to disassemble, increase degree of segmentation		x
2	Taking out: extraction, separation, removal, segregation		x
3	Local quality: uniform to non-uniform, fulfill different and useful functions		x
4	Asymmetry: change from symmetrical to asymmetrical, increase asymmetry		x
5	Merging: bring together, align, make parallel	Is there a way to eliminate the separate cutting, shredding, and grinding steps?	
6	Universality: multifunctionality	Are there new alternatives to CO2 lasers for low-cost, low-power cutting of biomass?	
7	Nesting: place one inside another or pass through		x
8	Anti-weight: compensate for the weight of an object		x
9	Preliminary anti-action: buffer, pre-stress, mask before exposure		x
10	Preliminary action: pre-arrange, pre-process		x
11	Beforehand cushioning: prepare for emergencies in advance		x
12	Equipotentiality: eliminate the need to move something		x
13	Inversion: invert actions, fix moving components, move fixed components, turn upside down		x
14	Spheroidality, curvature: bend what is straight		x
15	Dynamics: allow for change or movement	By moving the cutting blades and/or the conveyor, can we combine the cutting and chipping stations into a single step?	
16	Partial or excessive action: perform more or less of an action than necessary	Can we conduct a series of experiments to statistically determine how long the biomass should be processed by the cutting station to ensure it is sufficiently processed?	
17	Another dimension: switch from 2D to 3D, single to multistory, tilt or reorient		x
18	Mechanical vibration: cause oscillation, increase frequency	Could vibrating the feedstock conveyor bounce the biomass enough to improve cutting outcomes and allow us to eliminate the chipping station?	

Step 5: Develop your solution

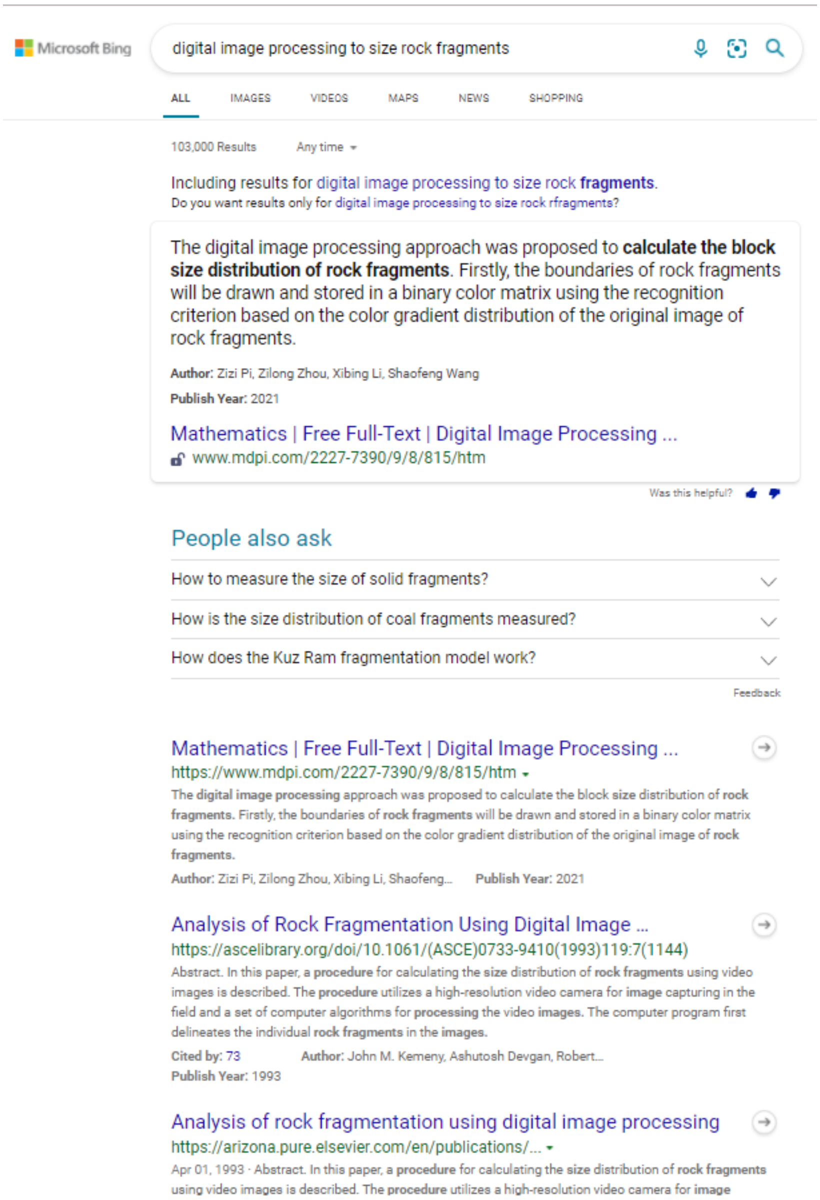
Finally, search the web or other information sources for a way to acquire a generic solution you have identified using the TRIZ methodology, or guidance on how to build it yourself. At this stage, start by searching for the generic solution as used in its original context. While doing so, watch out for sources of technical help or consulting you might need to adapt the generic solution and arrive at a specific solution to be used in the design of your product or service.

For example, after using the TRIZ tool for the biofuels example, suppose you identified a contradiction arising from the intersection of the improving feature "Quantity of substance" with the worsening feature "Device complexity" (cell AL29) using the TRIZ contradiction matrix

(Figure 4). You then identified TRIZ inventive principles that suggested useful generic solutions that might be applicable to this contradiction, which caused you to think of potential specific solutions to address the challenge of efficiently measuring the volume of cut materials (Figure 7). You previously found that mining operations use digital image processing to size rock fragments, and a commercial software package for this kind of digital image processing was available (Figures 5 and 6). Figure 8 shows that results from a web search for "digital imaging processing to size rock fragments" confirm that digital processing to solve this kind of optical sensor measurement problem is a proven method.

This suggests that you could try to adapt digital image processing technology to develop a project-specific solution that uses digital processing to address this contradiction for the biofuel mini-refinery.

Figure 8: **A screenshot of Bing hits on "digital imaging processing to size rock fragments" reveals that digital processing to solve this kind of optical sensor measurement problem is a proven method. Reading the hits leads to a commercially available package, Split-Online (spliteng.com).[1] This package can be used with any material. At Split-Desktop (freedownloadmanager.org) there is a free download with a one-time shareware fee.[2]**



1 Accessed October 9, 2021.
2 Ibid.

Be aware that you can apply more than one of the solution principles (TRIZ inventive principles) to your contradiction. In the digital processing example, you might combine this software-driven approach for measurement with one or more solutions for the device complexity problem, such as vibrating the conveyor belt or moving it back and forth for several passes to attain the sizes desired. Note that this approach may improve the sensors' digitally processed measurements because you can average a series of images as the pieces are moved or vibrated.

This conclusion is strengthened by searching for mining fragment sizing at the University of Arizona, where the size analysis software was developed. That search returns results such as a 2013 dissertation titled "Estimating Primary Fragment Size Distributions from Drill Hole Data" from its Mining and Geological Engineering Program (https://repository.arizona.edu/handle/10150/293750). Note also that such search results indicate a possible source for consultants or hires when developing your own solution for the biofuels mini-refinery.

How do you interpret the data in the TRIZ tool and use it in your NPD process?

TRIZ is a brainstorming tool for finding design contradictions and/or searching for design improvements using the TRIZ methodology. By following the five-step method described here, you are led to new design approaches which may be superior to the original approach. That said, it is necessary to ensure that the new solution does not create one or more different or new contradictions due to the interconnectedness of the pieces of a product or service design.

It is important to consider whether the new solutions identified using the TRIZ tool improve or worsen the overall value of the product or service for the customers and end-users on one hand, and the entities involved in developing, making, selling and supporting the product or service on the other. This applies both to solutions suggested by the TRIZ tool and to design choices suggested by using the Technology Forecasting tool. When looking at the data generated by using either of these tools, you should realize that this data contains, at best, a set of design improvement recommendations that must be considered in the light of results from using other tools in the Toolkit such as Business Model Canvas, Voice of the Customer (results concerning benefits and features sought), Competitive Advantage (analysis as to how your product or service compares with the competition), Value Chain (for the entity), and Portfolio Construction (for the entity). This consideration is a job for upper management, not the NPD team. Making the design improvement recommendations is theirs.

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