Design Thinking Tools' Series

Volume 1: **Space Time Cost (STC) Operator**

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1. Introduction: Problem in Pottery Industry:

A factory produced millions of pieces of glazed pottery - cups and plates. Each piece was twice baked in a kiln. All wares were screened with respect to quality after the first baking stage During the second baking stage, special temperature conditions were set for different screening groups. The screening process was done with a sound. The worker took a plate, hit it very gently with a special hammer, and then determined the degree of baking by the tone of the sound Workers called this process 'ringing the bell'. This was not easy work. All the shift workers were banging plates or cups. Listening to the sound and screening the product. Finally, some inventors decided to develop a robot for this task. This was a typical case, where the system had become obsolete and had to be replaced with something really new. The inventors understood that, but they could not walk away from that 'psychological image'. A machine with two 'hands' was built. The first hand held the date while the second hand hit the plate with a hammer. A microphone picked up the sound and an electronic device analyzed and commanded the first hand where to place the plate. The machine was installed at the factory. And very soon it was found that the machine worked more slowly than the workers. The inventors tried to increase the speed of the arms, but the machine started to break the plates. The machine was taken away and the workers continued to screen the product as they had done before. At first glance the task was simple - replace human hands with mechanical ones. The human arm, the palm, the fingers are tools that have the highest sensitivity and flexibility with the finest adjustments and control. The arm is controlled by the brain. This is a naturally perfected 'Brain-Arm' system.

Today we have sewing machines, bank stackers, fruit pickers and so on, all with robotic arms - trying to imitate the human arm. But in this pottery case, this robotic application kind of failed.
We need to change the principle of action, find a new method, one that is easy to mechanize and to automate.

We use a Design Thinking Tool called Operator STC (Space, Time, Cost).

1. What will happen, if the size of an object is decreased, or increased'?
2. What will happen, if performance time of an object increases or decreases?
3. What will happen, if the cost of the machine is zero, or very high?

How is the problem going to be solved under these conditions? These three questions of Operator STC, like crooked mirrors in a 'laughing room', distort the conditions of the task compelling our imagination to work and help to get rid of the obtrusive image of the old system. Can you imagine a plate the size of a dime, then an even smaller one, like a piece of dust?
You cannot pick up such a plate with your fingers, or strike it with a hammer. For a plate like that, a weightless hammer is needed. What if we increase the speed of the machine? Let's say, that the plate is of normal size, but we have only 1 second for the test, $1/1000^{th}$ of a second

1/1,000,000th of a second. During this short period of time, sound cannot get to the ears of the operator of the microphone. This means that something faster than sound is needed. Only light is faster than sound. What if the plates were struck by light? This *is* the weightless hammer! Could we catch the reflected light, and 'listen' to it?

Operator STC is not supposed to give you the answer to your problem. Its task is only to break-up our psychological inertia, which blocks our thinking process The strange mirrors of Operator STC are only tools for the first step to work on solving problems. If you have had experience with soldering, you know that the first step is to clean the surface from acids. A similar thing happens with our problem (and with our mind) when we use Operator STC. Take for example the problem with the glazed pottery. Operator STC prompted that it is good to replace conventional hammer with an optical hammer. For screening plates, this is a new method. May be this method has already been used in other applications? Maybe people have already developed instruments for this test? Then we can take that device and adapt it for our test, and that's it. Where else is it required to test ceramic parts? It is used in the production of electric resistors. Everybody knows that. Of course those resistors have to be tested. In size they are much smaller than plates. Resistors cannot be tested with sound, so people use light for that purpose. The amount of light reflected from resistors depends on the degree of baking. The machine sorts thousands of resistors per hour. A small change in this device would make it possible to use it for testing plates, and will ease the laborers from monotonous hard work.

Small objects are tested not with sound, but with light. For instance, a grain of rice that is 'cooked' by the sun could be controlled by light. There exists a patent on that process. By utilizing Operator STC we are deliberately complicating the problem, and at the same time we are searching for a simplified solution. This is happening because Operator STC helps us to get rid of our psychological inertia and enables us to look at the problem without prejudice.

2. Problem in Forensic Science:

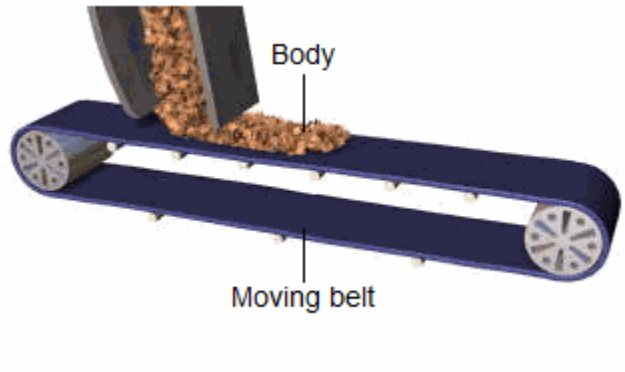
'This rifle should be examined', said an investigator as he placed the rifle on the table before the expert. 'I have to know whether or not this rifle fired a bullet a week ago'. The expert looked carefully at the rifle and nodded his head, 'I don't know how to tackle this task. The barrel has been cleaned and there are no carbon deposits.'

Let us use Operator STC ". Suppose that shot was fired a day ago or one hour ago or five minutes ago. By the specifications of the task there is no carbon deposit inside the barrel. If the shot was made ten seconds ago, then the barrel should be warm Then we could say even with closed eyes whether or not the shot was fired. Because the temperature 'memory' is very short,

we cannot rely on it after a short while. Let us find some other ‘memory’ that metal may have. What properties change during the firing of a rifle? Steel is demagnetized when the temperature is above the Curie point. It's magnetic characteristics disappear from shock as well. The gas from gunpowder hits not only the bullet, but the inside surface of the barrel as well. Usually the barrel has some magnetic properties, because of the magnetic field of the Earth. After the shot is fired the barrel is demagnetized. During the next three to four weeks the barrel regains its magnetic characteristics. The more time passes, the closer to normal the magnetic properties of the rifle will be. It is enough to compare the magnetic properties of two rifles in order to determine which rifle was used a week ago. In our case, Operator STC helped to uncover only half of the path to the answer. It reminded us about ‘temperature memory’. In order to switch to the ‘magnetic memory’ one should recall some physics. It happens very often: Operator STC gives you a hint, a prompt, and then you move forward.

3. Problem of Roller Conveyor:

Let's try to use Operator STC in problem involving transportation of molten glass over roller conveyor. Most rollers cannot withstand the high temperature of load (molten glass ribbons).They will themselves melt!



Let us imagine rollers to be very tiny. The diameter of a roller be about a hundred or even a thousand times smaller than that of a human hair To build this conveyor is practically impossible. However, because we are doing a mental experiment, we should not be afraid of doing so. Let's make the rollers as thin as molecules. We even break a molecule to get atoms (mentally).The melted glass ribbon will move over a layer of tiny balls-atoms. This could be the ideal conveyor. Under the glass ribbon we should spread ball-atoms. In control answer, atoms of liquid are used. A liquid that melts easily, has a high boiling point, and with specific gravity higher than glass is used. Its atoms act as rollers.

4. Problem with ship anchors:

A sea anchor embodies reliability symbol. It is impossible to count up as to how many thousands of ships this device has rescued for all history of navigation. But for modern huge ships, which have displacement in tens and hundreds and thousand tons, it isn't always reliable.

Indicator of reliability of the anchor is the relation (ratio) of restraining force to anchor's weight. It should be not less than 10-12. The restraining force must be 10 times dead weight of anchor. Thus a one ton anchor must give a stabilizing force of 10 tons. But in muddy sea beds or hard rocky beds, this ratio is not maintained. We need to redesign anchor of high efficiency.

The problem is set in already known terms. Each term reflects the old, existing technical solution. And these terms don't remain neutral; they impose inherent in them content and inertia to the inventor.

The invention consists in going out of limits, to impart new content to terms or completely replace them. It only seems to the inventor that in solving the problem he/she can go in any direction. This is a delusion. The inventor invariably “thinks by words" and these words (imperceptibly for him!) urge him to think in a certain direction. Seemingly, it is the inoffensive formulation of the problem, but the word ‘anchor’ imposes at once a certain way: maybe we should increase the number of blades to make them another form or to weight the anchor? Therefore one of the most simple and effective methods of removing mental inertia consists in the full refusal of special terms during the problem solving. It is necessary to use words, which are not containing concrete sense: “sphere”, “thing”, “object”, etc. (similarly “X” in the mathematics). For example: “the thing” which would keep the ship with force 100 tons is necessary”. Or “something should to be attached to any bottom with static friction of 100 tons”.

So, the main thing at the beginning of making a solution is to leave from the prototype and to suppress psychological inertia. We use Space, Time, Cost (STC) Operator. **-**

Operator STC includes six mental experiments,

Reconstructing terms of the problem:

Size of the object:

1. increases indefinitely ($S \rightarrow \infty$),
2. decreases to zero $S \rightarrow 0$;

Time of the process: (or inversely, speed of object’s movement)

3. increases to infinity $T \rightarrow \infty$;
4. decreases to zero $T \rightarrow 0$;

Cost : (admissible expenses) of object

5. increases to infinite $C \rightarrow \infty$;
6. decreases to zero $C \rightarrow 0$.

Experiments are subjective **-** here lot depends on power of imagination, from type of the problem and from other circumstances. However even formal execution of these operations sharply suppresses mental inertia.

General recommendations:

1. Each experiment should be made for appearance of a new quality.

2. Each experiment should be divided into discrete steps in order to reveal the appearance of a new quality. A step is a change of parameter of the object by order of magnitude.

Let's apply STC operator to the problem about the anchor. Parameters of which element of the system (ship, anchor, water, bottom ground) are necessary to change by using STC operator? The element that is necessary to be processed (ship) in order to find idea of the new tool "thing". Let the ship's length be 100m, width be 10 m, draught 100m/10m, depth to the ground is 1000m and time of lowering and fastening of the anchor, about 1 hour.

Let's give only those steps where the new quality appears.

1. S $\rightarrow\infty$. Let's increase it 100 times. The dimensions of the ship became 10 km/1 km. How to solve the problem now? The ship "sits" on the ground and doesn't need to be attached to the bottom. Transfer this new quality on the usual ship. To be attached to the iceberg? To flood bottom part of the ship during mooring? To separate a part of the ship and to lower on the ground? Underwater sail's use of the water for braking?

2. S $\rightarrow$0. Let's reduce it 1000 times; the dimensions of the ship become 10 cm/1 cm. How to solve the problem now? The ship is so small (as a chip) that the length and weight of rope (thin wire) much more exceeds lifting force of the ship. It will be uncontrollable or will sink.

3. T $\rightarrow\infty$. Time of process is 10 h. The fastening goes slow, it is possible to penetrate into the ground deeply: to hammer a pile, to screw into the ground. There are screw anchors. Vibroanchor was patented in USA. Under vibration from the electric motor, the lower end deeply enters into the ground (restraining force is in 20 times more than weight). This solution isn't very efficient for rocky ground though.

4. T $\rightarrow$0. Let's reduce time by 100 times. Very heavy anchor so that it has a short time to fall down quickly is necessary. By 1000 times now. The anchor is like a rocket. In 10000 times attachment by explosion; "welding" to the ground with the help of exothermic mixture.

5. C $\rightarrow\infty$. The allowed cost of "thing" is unlimited. It is possible to use the most unusual ways and expensive installations (a platinum anchor, usage of rockets, submarines, bathyscaphes, etc).

6. C $\rightarrow$0. Thing" costs nothing, for example, as water. How to make the anchor of water?

The control answer: Patent 1 134 465, the anchor is made in the form of a metal plate with the refrigerating unit. With its weight of 1 ton and capacity of the refrigerator **as** 50 kilowatts the restraining force reaches 200 tons in 1 minute, and in 10-15 minutes, it reaches1000 tons!

5. Real Problem Solved by a Startup in Europe: Mechanical device for separating potato roots from clods.

Existing solution: There is a mix containing clods + stones + potato roots. We need only potato roots (no clods, no stones for sure). Mix is delivered on the conveyor. After conveyor at output, the mix contains 20% clods + stones together and 80% potato roots. Also 4% of potato roots are damaged.

Asked solution: Output mix should contain 0% clods +stones, 100% potato roots and 0% damaged potato roots.

Take into account the following: Roots and clods do not differ in dimensions, but their density is different to each other. And of course, stones have a density different from both. How to use this difference of properties in designing and manufacturing a novel machine?

Using STC method, the Startup arrived at a brilliant solution that made them profitable in first 3 months.

For division potato and clods on density it would be necessary to create "pseudo-liquid" in which potato can float, and clods move down. Pseudo-liquid condition is created with the help of nylon balls placed in a field of vibration. Vibrobunker is filled with balls strung on a thread. Frequency of vibration is chosen such that balls kind of float - a pseudo-liquid condition. On the top layer of balls the (lighter) potato flow while (heavier) clods hit each other and move down through balls. Of course the heaviest stones sink even faster.