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RESEARCH ARTICLE

AN EXAMINATION OF GOLDRATT'S THEORY OF CONSTRAINTS AS A SCIENTIFIC THEORY: USING THE THINKING PROCESSES TO PROPOSE THE "STRUCTURE OF A HYPOTHESIS" AND THE MYSTERY ANALYSIS PROCESSES

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ABSTRACT

The Goal written by Goldratt and Cox published in 1984 has been a best seller for over 30 years. The scientific management theory introduced in this book is Theory of Constraints (TOC). Since its introduction, TOC has been successfully applied to many different functional areas (production, cost accounting, sales, R&D, IT, logistics, etc.) organization environments (projects, supply chain, etc.) and industrial sectors (manufacturing, government, education, healthcare, etc.). What is remarkable about TOC is that it is simple and robust and brings reproducible, rapid and significant bottom-line results. Goldratt devoted his life to making TOC a "theory" in the social sciences at the same level of rigor as "theory" is understood in the hard sciences. This article examines TOC as a "scientific" theory. The logical "structure of a hypothesis" (SOH) is defined by examining the requirements for a theory to be scientific. Because of its simple, practical and graphical structure this SOH provides researchers the ability to clarify thinking, communication, testing and validation of research in both social and hard sciences.

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INTRODUCTION

In 1984, *The Goal* (Goldratt, 1984) by Goldratt and Cox was published and today it still remains on the best seller list. Though not called theory of constraints (Goldratt, 2011) until five years later, The Goal presented this scientific management theory. Since its introduction, TOC concepts, processes and tools (Cox, 2010) have been applied to many different functional areas (production, logistics, distribution, cost accounting, sales, R&D, etc.) and industrial sectors (manufacturing, services, government, education and healthcare) where it has been achieving significant breakthrough results. How can TOC apply to so many different environments and achieve remarkable results in these very diverse environments? As a physicist, Dr. Goldratt applied the concept of "cause and effect", a concept widely utilized in the hard sciences, to problems in organizations involving people. He devoted his life to making TOC a "theory" in the social sciences at the same level as "theory" is understood in the hard sciences.

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In this pursuit, many (Kishira, 2016; Tobita, 2014) believe that his work can also advance the application of theory in the hard sciences. What is remarkable about TOC is that it is simple and brings reproducible results (See for example, the numerous applications with students of all ages on the TOC for Education website (Suerken, 2011). The purposes of this paper are two-fold. First, TOC is examined to determine whether it is a scientific theory. The requirements for a theory to be scientific in social sciences as well as in hard sciences are described. Second, using the TOC thinking processes (TP), the logical "structure of a hypothesis" is defined. A major chronic problem in Japanese industry is analyzed to illustrate this structure of a hypothesis. This logical approach to structuring and analyzing a problem and identifying a potential solution can help address challenges and problems in both social and hard sciences as well as in personal lives.

TOC as Scientific Management Theory

Kaizen and Gemba are common and important concepts in Toyota as well as in other Japanese companies. Kaizen means "improvement" and Gemba means "place of work".

It is thought that accumulating each Kaizen on Gemba (adding all improvements at the places of work) contributes to improving the company's performance as a whole. The idea seems to be obvious and has been implemented throughout Japanese industry. But is it true? Even though all employees do Kaizen everywhere in the company and targets are met in most places, many cases exist where the company's performance as a whole has improved only slightly or hasn't improved at all. How can so many employees work so hard and the company not improve significantly? Why does such mysterious phenomenon occur? How can we examine and resolve this issue? Dr. Goldratt developed the TOC thinking processes (TP) to better analyze and solve such propositions. In order to examine the basic premise of TOC, think of why the phenomenon, in which Kaizen as a whole (the sum of local improvements everywhere) does not lead to improving company performance as a whole, occurs. Suppose you work in an organization, answer the following questions:

- Is your work dependent on other employees work? Or does their work depend on your work?
- Are your and other employees' capacities the same?

You and other employees would answer no to both of these questions. Why? Because there are "interdependencies" and "variability" in most organization's activities. If you look at the flow of work in organizations, for example in the links from customers to sales to design to production to logistics to customers, you probably could explain the interdependencies among employees and you probably could conclude that it is impossible that each link has the exactly same capability. Note also rarely is production a bottleneck in the work flow of a company. If you were in times when you can sell as much as you produce, your bottleneck is production so you got bottom-line results by improving the production bottleneck; however, if limited opportunities to receive customers' orders were a bottleneck then sales is the bottleneck; it should be obvious that it is difficult to get bottom-line results as a company by improving production when it is a non-bottleneck. Figure 1 shows a model of an organization with "interdependency" and "variability" in resource capacity.

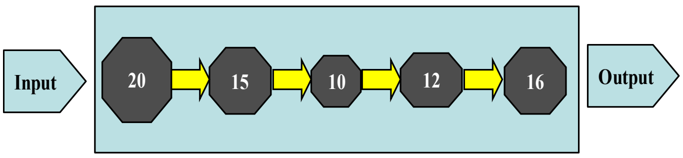


Figure 1. System with "interdependency" and "variability"

Work flows across stations (work centers, departments, etc.) from left to right, but capability for each station (in units) varies as follows: 20, 15, 10, 12 and 16 per day. How much is the daily output of this system (company, organization)? It is obvious that the daily output cannot exceed 10 units which is the bottleneck. Let's examine the bottleneck in more detail. If you know which station is the bottleneck, you deal with it directly. So, the bottleneck will not be a bottleneck anymore, productivity of a whole system should go up. However, in reality in many companies doing this is not easy because the bottleneck is usually a resource such as excellent personnel or expensive equipment that cannot be increased in the short run. Can you increase excellent personnel right away? Can you add expensive equipment right away? Here you notice that (even after improvement efforts) the resource that cannot be increased easily tends to become the bottleneck even though you knew it might be the bottleneck. The resource that cannot be increased easily is, in other words, a scarce resource. If you examine the work content of a scarce resource (e.g. excellent personnel), you will find out that he/she most likely does not always focus on what only he/she can do. Not only that, he/she tends to become busy with other tasks because everybody relies on him/her knowing his/her excellence. Needless to say, it is people who do the work. It is impossible to improve the quality of work when the bottleneck is continually overwhelmed with work. It is obvious that lowering the quality of work of the constraint in an organization affects the performance of the whole organization.

Assuming you are the bottleneck of your company please answer the following question:

How much time in a day do you focus on what only you can do?

If you think holistically, it is quite seldom that the scarce resource which is the bottleneck of the whole company is fully performing to its potential. If you find the bottleneck, your Kaizen approach would be totally different. You just need to focus on improving the bottleneck. By all employees focusing supporting and improving the bottleneck, significant bottom-line results should come faster and your focused Kaizen would be more effective than the current approach of trying to improving everything. In short, you can get bottom-line results faster and easier. It is not rare when people understand that the overall performance will improve if their attention is on a certain point (the company's strategic point) then they start to help each other.

It is obvious that "where there are interdependencies and variability, there must be a constraint somewhere. Focusing on improving the constraint brings results to the whole." In short, performance as a system is determined by the constraint. In TOC, we regard a whole organization as a "system". According to the Oxford English Dictionary, system (System, 2017)is defined as: "A set of things working together as parts of a mechanism or an interconnecting network; a complex whole." Therefore, recognizing an organization as a system composed of multiple elements rather than one whole element is not just obvious but also important. For this reason, assuming there are both "interdependencies" and "variability", we can focus on the bottleneck for holistic improvement of an organization. As the application of TOC expanded to other environments, the word "bottleneck" was misunderstood and inappropriate; thus, Dr. Goldratt (System, 2017) carefully selected the word "constraint" instead and developed the "Theory of Constraints" - focusing on the constraint is the foundation for holistic management to achieve significant bottom line results rapidly. Let's use Figure 1 to examine the effect of Kaizen focused on non-constraints. Suppose the fourth work center's capacity is increased from 12 to 15 by Kaizen. It is obvious that improvements on non-constraints will not bring any results as a whole. However, it means more than that. Considering the reality that resources (both personnel and financial) in organizations are limited, using limited resources on improving non-constraints is not just a Muda (waste in Japanese); it also means that it is taking away resources from improving the constraint. It is obvious (Goldratt, 2011) that "spending resources on improving non-constraints is not just waste, but it damages the improvements of a whole organization. "If you are facing the situation where everybody is working very hard in their areas but the result is not following as expected, there is a high possibility that most of your improvement effort is irrelevant and is being spent on non-constraints. When each employee improves without considering "interdependency" and "variability", the result is in local optimization everywhere which wastes most or all of the improvement efforts.

To the question "what is TOC in a single word?", Dr. Goldratt (Goldratt, 2010) answered the following

"TOC in a single word is FOCUS: do what should be done AND don't do what should not be done."

Today, TOC is not merely an improvement method for production; it can be applied anywhere in an organization where there are "interdependencies" and "variability". More than that, TOC is very simple and easy to understand and apply because all you need to do is to focus on the constraints. This translates to having employees perform Kaizen activities to support the constraint. The breakthrough results demonstrated in organizations across the world are understandable. See the TOCICO website Success Stories (Cox, 2013) for case studies across several functions, environments, and industrial sectors.

Hard Science Approach

Dr. Goldratt described the evolution of TOC in his last public appearance (Goldratt, 2011) as follows

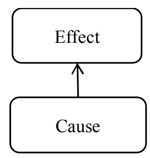
"I took the concepts of physics, the approach of physics, and I applied it to, not to the material world like physics or chemistry is doing, not to atoms or electrons or molecules or enzymes, but to human relationships, to organizations. Yes, when I started, people told me 'Eli, you are totally out of your mind, because people are not predictable.' And I've said, 'Really?' I think that I can predict very well what will happen to me when I tell my wife my true opinion about her new dress. What do you mean people are unpredictable? If they are not predictable there is no base for society. There is no base for family even. Yes, people are not 100% predictable but so is the weather. Why won't we take this vigorous cause-and-effect thinking, this demand for proof of what you are saying and apply it to the social world?"

To show the relationship between cause and effect, Dr. Goldratt took the approach of using diagrams rather than formulas. See Figure 2a. The entity at the base of the arrow is the cause and the entity at the tip of the arrow represents the effect. The arrow represents causality. It is read: if cause then effect. It becomes easier for everybody to see and question the causality you believe exists in a situation (or environment) by using diagrams. These diagrams make it possible to logically discuss problems especially in a team environment. While developed and taught in the early 1990's in two-week Jonah courses, Dr. Goldratt (Goldratt, 1990; Goldratt, 1994) formally introduced this methodology "Thinking Processes" (TP) in his book, "It's Not Luck"(Goldratt 1994). In one TP structure, we use three elements illustrated in Figure 2b to examine the link between cause and effect. The structure consists of only three elements, and is so simple that anybody can use it to think logically.

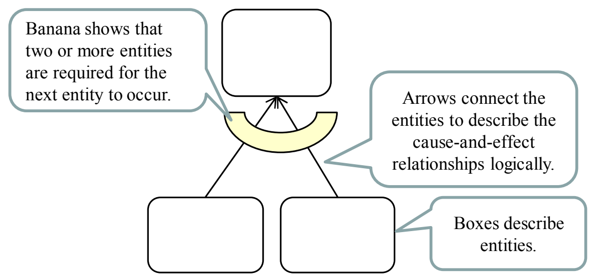
The three elements are

- A box containing a description of the entity (an action, condition, or effect).
- An arrow connecting the entities to express the cause-and-effect relationship logically.
- A banana (a hand-drawn banana shaped ellipse connecting two or more incoming arrows named by Dr. Goldratt) showing that two or more entities are required to exist for the effect entity to occur.

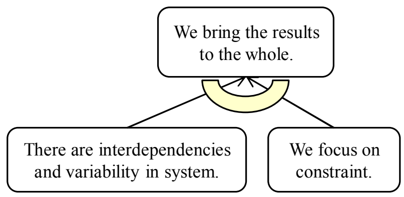
For example, an effect is caused by the existence of a condition and an action being taken.



a. Cause-and-effect relationship.



b. Three tools for thinking logically.



c. Logical description of TOC.

Figure 2. Cause and Effect thinking and TOC

In Figure 2c, this logical structure describes the use of TOC in systems. When you read the relationship between cause and effect, you use "If… then…." For boxes connected with a banana, you use "and". The general structure is: If … and … then …. Our example is:

If "there are interdependency and variability in a system" and "we focus on the constraint" then "we bring the results to the whole".

You might feel intuitively that something is missing in this description. If so, that is a proof that people can verify logical connection between the cause and effect by reading it out loud. For a more structured approach to verifying the logical connections, Dr. Goldratt developed the Categories of Legitimate Reservation (CLR) (Scheinkopf, 1999) to improve clarity and verify logical connections in the TP. The CLR are: Clarity, Entity Existence, Causality Existence, Cause Insufficiency, Additional Cause, Cause-Effect Reversal, and Predicted Effect Existence. These CLRs are useful in strengthening and validating one's intuition.

According to the Oxford English Dictionary (System, 2017), intuition means "The ability to understand something instinctively, without the need for conscious reasoning". In other words, you are in a situation where you can feel something is missing but you cannot explain it logically. Even though each entity in Figure 3a has previously been discussed the logic still doesn't feel right because our intuition tells us that the diagram is missing the reason why these two phenomena cause "we bring the results to the whole". Let's identify the missing entity. Formally, when you think about what is missing, you use the logic of necessary condition; you use the logic of sufficient condition to check if what is missing is correct. This is how you check the logic of necessary and sufficient conditions. Applying this to our example, you are aware that:"if there are interdependencies and variability, then there must be a constraint somewhere". In such a situation, it becomes obvious that "performance of a whole system is determined by its constraint".

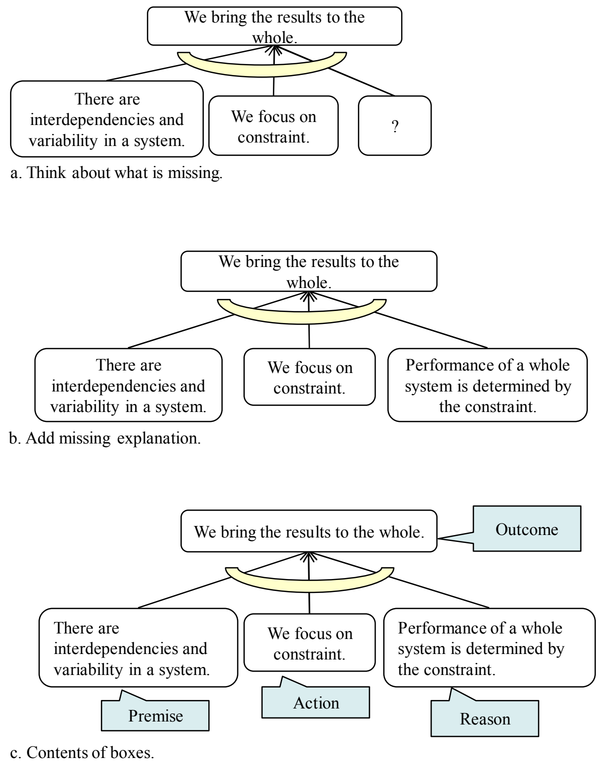


Figure 3. Logical structure of TOC thinking processes

As you notice, "performance of a whole system is determined by the constraint" is a powerful statement. It is because this statement provides the reason to focus on the constraint. This realization translates to: one doesn't need to improve everywhere in a system and conversely the organization should change its improvement initiatives to focusing on the constraint. If you make Kaizen everywhere in your system, it is probably because you think all improvements would bring organization results. However, it is not true. Even if somebody gives an order to "focus on the constraint!", people won't follow it well. It is not easy to overcome inertia that has been in the organization for a long time. "Performance of a whole system is determined by the constraint" - The reason leads people to the desired behavior. When people realize this truth, they say "it is eye-opening!" It is probably because you realized an unnoticed underlying truth although it becomes only "common sense" after the realization. In a system with "interdependency" and "variability", there is always a constraint.

TOC tells people that focusing on the constraint brings results to the whole; however, many would say "it is common sense". To those, Dr. Goldratt said "common sense is not common". Once it is understood it is "common sense". Dr. Goldratt (Goldratt, 2011) described the accomplishments of winners of the Nobel Prize.

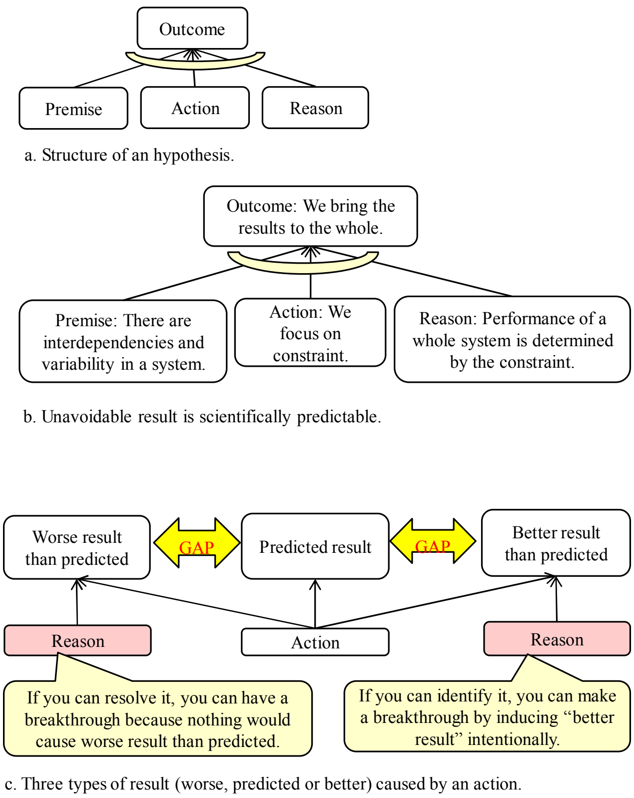
"You have to publish one single article, that's enough. But the article must be on the level that when any other physicist reads it, the reaction is 'Oh, Shit!' That's a Nobel Prize. It is the hardest thing: looking at a reality so complex to find how to understand something so obvious it's called common sense. It is a hard thing to do but it's the only thing that works."

When we find the logical (cause and effect) connection which can explain in a way everybody can understand, that is when people say it is only 'common sense', which Dr. Goldratt believes is the highest compliment one can receive.TOC has been making breakthrough results in various fields. TOC stands for the Theory of Constraints. Why did Dr. Goldratt select the word "theory" for what he devised, not "method" or "system"?In the Kojien Dictionary, the most popular dictionary in Japan, the definition of theory has recently been changed. In the 5th edition(1998), the meaning of theory was "universal systematic knowledge that can explain an individual fact or recognition uniformly"; in the 6th edition(2008), it is "universal systematic knowledge that can explain and predict an individual fact or recognition uniformly in science". With the definition of 5th edition, theory can be established when you can make the explanation of what happened before; however, in the 6th edition, theory is defined as "universal systematic knowledge that can predict… in science". Thus, it is not considered theory in science just to be able to explain something later. Theory in science must be systematic knowledge to be able to predict something before. To sum up, Dr. Goldratt devised TOC as a "theory" that is "universal systematic knowledge that can explain and predict an individual fact uniformly in science".

Definition of the "Structure of a Hypothesis"(SOH)

In the social sciences, there are many known theories and methods. What makes TOC different from those is that the TP can be used to logically predict what is going to happen and when and why the results occur. Prediction is common in the hard sciences. In the hard sciences, it is hardly referred to as a theory when we can't logically predict a result and realize the prediction. Dr. Goldratt applied the concept of the hard sciences to the realm of social sciences, and developed theory called TOC, which can logically predict at the same level as in the hard sciences. The question then is whether only TOC is special in the field of social sciences. What is required for various theories in the social sciences to attain "scientific" status to the extent of the hard sciences?

Karl Popper (Popper, 1957) tried to answer the question: "when should a theory be ranked as scientific?" He claimed falsify ability distinguishes between science and pseudo-science. The criterion is its refutability (risky prediction) or testability - this concept is reflected in the definition of theory provided the 6th edition of Kojien Dictionary (2008). Using this concept of falsify ability one must be careful not to dismiss theories in the social sciences as useless even though they might not yet be ranked as "scientific". Many theories and methods that are widely known and supported in the social sciences are useful to society but have not attained logical predictability to the extent of the hard sciences. It can be significant for theories and methods in the social sciences to attain "scientific" status. TOC is "scientific" not by coincidence; there must be a reason. By revealing it, I would like to derive the condition to attain the "scientific" status. First, let's examine what's in each box in Figure 3b. As described in Figure 3c, the box "there are interdependency and variability in the system" is a premise (the Given, or condition), "we focus on constraint" is an action (the cause) to cause the outcome (the effect), and "performance of a whole system is determined by its bottleneck" is the reason (why the cause creates the effect), and "we bring result to the whole" is the outcome. The structure of the relationship between cause and effect illustrates scientific thinking. Figure 4a shows the generalized structure of a hypothesis.



a. Structure of an hypothesis.

b. Unavoidable result is scientifically predictable.

c. Three types of result (worse, predicted or better) caused by an action.

Figure 4. Structure of an hypothesis expanded to predicted results

This is the logical structure: the outcome is unavoidably induced by these three items: premise, action and reason to cause the result. I named it "structure of a hypothesis". In this "structure of a hypothesis", the "outcome" can be logically predicted by three items: "premise", "action" and "reason". Although adding a logical description like "if … and … then … because…." could sound too formal, when we are aware of each premise, action, result and reason during a discussion and we can express them more naturally: If we have the premise of "there are interdependencies and variability in the system" and take an action of "we focus on the constraint", the result of "we bring results to the whole" will happen because of the reason of "performance of a whole system is determined by the constraint". Let's consider your daily work. If you work in a system where there are interdependencies and variability you probably noticed that you do not have to improve everything and you can scientifically predict bringing results to the whole by focusing on the constraint. See Figure 4b.According to the Kojien Dictionary (2008), hypothesis is defined as: "supposition made to explain a certain phenomenon uniformly in hard science and other areas. By verifying the logically derived outcome through observation, calculation, experiment etc., supposition becomes valid law or theory in a certain limitation". A hypothesis is still a hypothesis. Noe (2015) succinctly summarizes: "Popper claims that scientific theory will never be established as the perfect theory, but it will always be in a position of a 'tentative hypothesis' yet there is exceptional value with the scientific theories that have been surviving for years through many refutations."In this sense, TOC has verified in various fields and survived, so it is a valid theory in a certain limitation or given condition which is a "system with interdependencies and variability". The "structure of a hypothesis" can be used to build, test, and verify hypotheses in the social sciences, but it is obvious that it can also be used in the hard sciences. Therefore, we can establish and verify hypotheses scientifically in the same way for both the hard sciences and social sciences. Using this TP logic diagramming structure makes the researcher explicitly state the causal relationships of the hypothesis.

Application of the Structure of a Hypothesis – Learning from Failure: Mystery Analysis

Scientists develop new knowledge by repeating the process of making a hypothesis, conducting an experiment, examining the result and modifying the hypothesis. It is very rare to have predicted the result in the first experiment. It is widely known that every failure is a stepping stone that leads to success, so scientists must have the mindset of learning from failures. Let's examine what it means when things do not go as predicted. As in Figure 4c, there are only three types of results induced by an action. The first possibility is that the experiment achieves the "predicted result". Everything went as predicted, so we can assume the hypothesis is correct. The second possibility is that the experiment achieves a "worse result than predicted". People call it a failure when something did not go as predicted, but there must be a reason for the failure. If you can identify and resolve the reason for the failure then you are a step towards a breakthrough because worse result than predicted would not happen again. The third possibility is the experiment achieves a "better result than predicted". We should consider this as a problem also because the experiment didn't achieve the "predicted result" even though it is "better result than predicted". There must be a reason that caused the "better result than predicted". If the reason can be identified then a breakthrough may have caused "better result than predicted". Figure 5 shows the cause and effect structure to analyze when you get a whole result than predicted. I named this process "Mystery Analysis" (Kishira, 2014) because it is useful in explicitly determining the reason why the experiment result wasn't achieved as predicted.

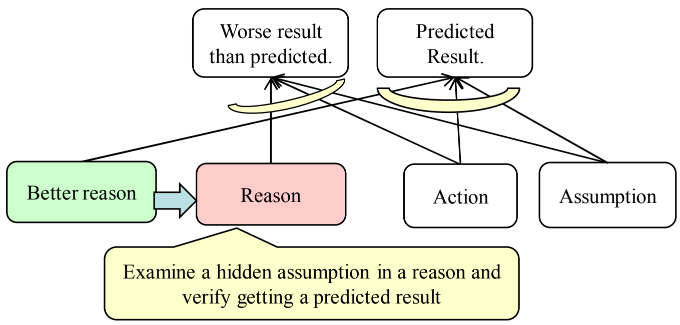


Figure 5. Structure of mystery analysis

To illustrate the application of the Mystery Analysis, let's continue with our previous discussion on Kaizen. All employees work hard at their jobs but the expected bottom-line result does not follow. In this case, it is natural to think that you will get the result for the whole organization if everybody works hard at performing their work.

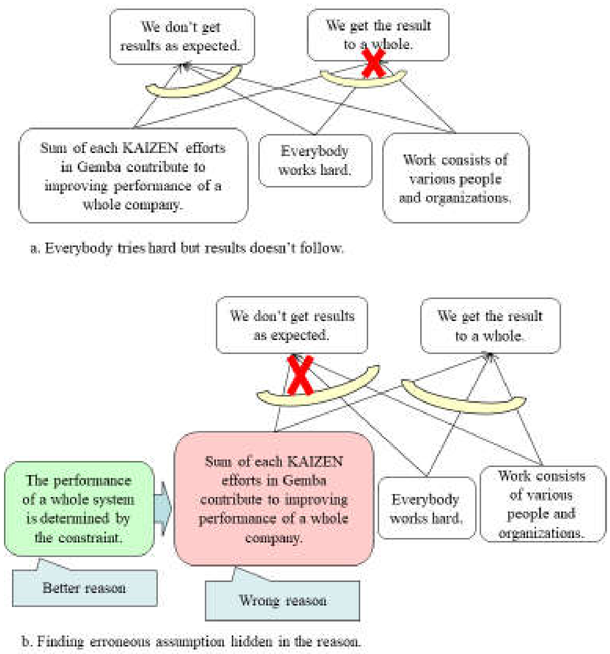


Figure 6. Mystery analysis example

If you do not get the result as expected, there must be a reason. Figure 6a shows the logical structure of this problem. Is the reason of the "Sum of each Kaizen effort in Gemba contributes to improving performance of the whole company" true? It is obvious that this reason must be an invalid assumption. If there are interdependencies and variability in work flow that consists of various employees then a constraint must be somewhere in the system. If so, it is no wonder that Kaizen efforts on the organization's non-constraints do not lead to the expected organization outcome. As you are aware, financial and human resources are limited. Therefore, working on non-constraints delays Kaizen on the constraint. In other words, you need to be careful that Kaizen efforts on non-constraints might result in preventing Kaizen as an improvement to the whole organization. Thus, it becomes obvious that when everybody works together to focus all Kaizen efforts on the constraint (instead of trying to improve their local areas), it will lead to overall performance because "the performance of a whole system is determined by the constraint" as shown in Figure 6b.What is good about this graphic logical method is that it enables focused and effective discussions among groups. Because the logical relationships are explicit, a group can work together to objectively determine the cause of the unexpected result. This approach enables effective discussions about breakthrough ideas. It creates a collaborative process to accelerate innovation by involving the various stakeholders. This is significant. Today's innovations require knowledge and cooperation from various experts in different fields. Needless to say, the productivity of creating innovations increases when experts from different fields collaborate. The quality of discussions and the intellectual productivity dramatically increase in addition to a reduction in the time associated with discussions when using this method. The following is the comment (Kishira, 2014) from Dr. Shinya Yamanaka M.D., Ph.D., who won a Nobel Prize on his invention of iPS cell and has experienced this process. *Scientific experiments are very much a process that learns from failures. But when we make a mistake, we feel down and try to not make more mistakes; it might lead us to avoid adventurous challenges.*

However, failures or things not going as expected should be gold mines for new discoveries. There is no success where there are no failures.

As scientists, we think logically for our research on a daily basis. This is because we firmly believe that thinking logically will lead us to an answer. I don't know why but I assumed that it was not applicable to things unrelated to research. Teamwork is indispensable in scientific research. For me, TOC's way of thinking was just eye-opening knowing that thinking logically is more important in human aspect to lead us to an answer. It made me realize that it is okay to think like a scientist in regards to managing research and development where people are working. It is obvious that thinking logically is important on things other than research, but in the area of science, it is crucial. There might be wrong assumptions hidden on things you assumed to be true. Even if you come up with a textbook answer, it adds no value to the society.

It is common sense to manufacturers that developing a similar product to a competitor will not sell so much. We need to aim to answer a question that no one in the past was able to answer, to an extent that it will be added onto the textbook.

We might not be good at thinking logically, but maybe that is only because we did not have any training to be so. But we are good at learning. Therefore, if we can train ourselves to think logically, we should be able to come up with an innovation that could be in the textbook.

Photo 1. Dr. Shinya Yamanaka with mystery analysis

Mystery Analysis is very simple and easy; therefore, not just scientists but also ordinary people and even children can use it. Compared to adults, children are more flexible and creative in their thinking. It is exciting to see children discover something new by connecting cause and effect logically. See for example, a case study (Yasuda, 2016) in which elementary school children solve a class disruption problem by themselves. Many such case studies are provided on the TOC for Education website (http://www.tocforeducation.com/). Conducting a Mystery Analysis is to think like a scientist using the "structure of a hypothesis". It is probably not just me that feels that the future is bright by seeing children who can think naturally and logically like scientists. Furthermore, an unexpected result can always become an opportunity to have a breakthrough by using the Mystery Analysis. Dr. Goldratt claimed *"everyone can reach the status called as a genius".* By training ourselves to consciously connect cause and effect more and more, you will be able to think logically more and more. Then, you will be able to see causality in matters that before seemed to have no connection, predict an unexpected result ahead and even validate it. People would call the person who can do those things a "genius. Dr. Goldratt stated (2011):

"Take a regular person. Let this person practice for years. After 20 years, you will not see a thin person, you will see mountains of muscles. Then people say how strong he is. Yes, he is. But he was not born like that. He made it. The same thing with our brain. When you start to think clearly, people start to call you a genius."

To Think Like a Scientist

In the Goldratt family, it is tradition for parents to constantly ask their children "What is your goal in life?" You would probably understand this question is taken seriously and also that it is not easy to answer this question. Dr. Goldratt struggled for several years with answering this question. When he was twenty years old, he chose his goal in life "to teach the world to think".

People inherently have the ability to think. However, in school education, children are mainly taught to "memorize" rather than to "think". That is why Dr. Goldratt developed the TP methodology to enable educators to teach students how to think logically. Why don't people always utilize the ability to think even though they inherently have the ability? Dr. Goldratt explained that there are four obstacles that prevent people from thinking clearly.

- The perception of reality as complex
- Blaming others
- Accepting conflicts as given
- Thinking that you know.

Do you think that any good results will come out from "the perception of reality as complex"? Scientists naturally assume that there must a simple rule governing various phenomena. Without this assumption, it would be impossible to have technology improvements. To think that "every situation is simple" (once understood) is a natural attitude for scientists. Do you think that any good things will come from "blaming others"? It is obvious that blaming others cannot be the solution for a problem. You become more distant from solving problems by "blaming others". "Blaming others" is not a rational way to solve problems. If you cannot blame others, what can you blame? How about blaming "assumptions" related to the system? This is what we normally do in scientific experiments. When we get a result that is different from our prediction, what we normally think is that there must be an invalid or unspoken assumption somewhere. Blaming others will not solve a problem. Therefore, by always assuming that "people are good", you would be able to find wrong assumptions about the system that created the problem and move forward on solving the problem. Finding wrong assumptions and replacing them with better assumptions to explain phenomena is the way to evolve science theory so it is also a natural attitude for scientists. Do you think that any good things will come out from "accepting conflicts as given"? Scientists would think it is an opportunity to make a breakthrough when encountering unsolved conflicting ideas. Scientists can never make breakthroughs unless they think "there is always a win-win solution". What unavoidably happens by resolving conflicts is harmony. In other words, conflict is an opportunity to create harmony. Dr. Goldratt paid great respect to the Japanese culture that values "harmony". By examining how true harmony can be brought, Dr. Goldratt noticed that eagerness to have harmony is the reason for not being able to have true harmony. Dr. Goldratt (Goldratt, 2008) said "Wishing to have harmony leads to avoiding conflicts with other people. Hiding the conflicts under the carpet does not resolve them. Harmony will come after resolving conflict."

Do you think that any good things will come from "thinking that you know"? Your learning stops there. If you are in a place that you think you know, it means that you have obtained a more solid foundation than before. It is an essential attitude for scientists to "never say I know" to evolve knowledge by taking this more solid foundation as a base for the next jumpin knowledge.

Dr. Goldratt has developed the following four beliefs to overcome those four obstacles

- Every situation is simple
- People are good
- There is always a win-win solution
- Every situation can be substantially improved – Never say I know.

As you noticed, the four beliefs provide the mindset necessary to think like a scientist. By overcoming the four obstacles with this mindset, you will be able to think more clearly, keep learning from failures, turn every occasion into an opportunity and have the ability to collaborate with others. As a result, you will gain meaningful successes in your eyes. This would lead you to have a full life. Dr. Goldratt (Goldratt, 2008) describes philosophy of life that allows you to achieve "a full life" by overcoming those four obstacles.

DISCUSSION

The "structure of a hypothesis" is defined by examining the requirements for a theory to be scientific in the social sciences as well as in the hard sciences and by examining TOC as a scientific theory and further addressing the need and possibility for a better society with the wide-spread use of "structure of a hypothesis". Many books and articles on management are available today. Muchcan be learned from them but is the learning effective or just memorization? Understanding the system and its cause-and-effect relationships to achieve the system goal seem far more important to addressing many organization problems. The logical connection between cause and effect is not always clear; in many cases, you might misunderstand because the premise and the reason that comprise the cause for the result are not clear, or you do not get an expected outcome without knowing there is a premise needed to deliver the expected outcome. In the field of social sciences that deals with people and organizations, most theories have not yet achieved the status of the hard sciences in terms of scientific prediction and reproducibility. Scientific theory will never be established as the perfect theory and will remain as tentative hypotheses. "Structure of a hypothesis" introduced here is also a tentative hypothesis yet can be practically used to simply describe the logical structure of a hypothesis. In the longer term, I hope that "structure of a hypothesis" helps to create a better society by contributing to evolve social science theory into scientific theory as in hard science. I would like to conclude this discussion with a quotation from the introduction in "*The Goal*" by Dr. Goldratt.

"Finally, and most importantly, I wanted to show that we can all be outstanding scientists. The secret of being a good scientist, I believe, lies not in our brain power. We have enough. We simply need to look at reality and think logically and precisely about what we see. The key ingredient is to have the courage to face inconsistencies between what we see and deduce and the way things are done. This challenging of basic assumptions is essential to breakthroughs. Progress in understanding requires that we challenge basic assumptions about how the world is and why it is that way. If we can better understand our world and the principles that govern it, I suspect all our lives will be better."

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REFERENCES

Cox III, J.F. 2017. *Success Stories*. Theory of Constraints International Certification Organization (cited 2017 October 21); Available from: http://www.tocico.org/.

Cox III, J.F. and J.G. 2010. Schleier Jr., *Theory of constraints handbook*, ed. J.F. Cox III and J.G. Schleier Jr. New York, NY: McGraw-Hill Publisher.

Goldratt, E.M. 1990. *What is this thing called theory of constraints and how should it be implemented?* 1990, Croton-on-Hudson, N. Y.: North River Press. x, 162.

Goldratt, E.M. 1994. *It's Not Luck*., Great Barrington, MA: North River Press.

Goldratt, E.M. 2008. *Preface*, in *The Choice (Japanese edition)*. Diamond Inc.: Tokyo, JP.

Goldratt, E.M. 2010. *Chapter 1 Introduction to TOC— My Perspective*, in *Theory of Constraints Handbook*, J.F. Cox III and J.G. Schleier Jr., Editors. McGraw-Hill Publisher: New York, NY. p. 1-9.

Goldratt, E.M. 2011. *Above and Beyond the Competition: A Conversation With Eli Goldratt*, in *Above and Beyond the Competition: A Conversation With Eli Goldratt*, E.M. Goldratt, Editor. Baltimore, Maryland.

Goldratt, E.M. 2011. *Never say I KNOW - Day 1 Introduction presented by Lisa Scheinkopf*. in *TOCICO International Conference: 9th Annual Worldwide Gathering of TOC Professionals*. Palisades, NY: Goldratt Marketing Group.

Goldratt, E.M. 2011. *Never say I KNOW - Day 2 The tangibility of the green curve presented by Lisa Scheinkopf*. in *TOCICO International Conference: 9th Annual Worldwide Gathering of TOC Professionals*. Palisades, NY: Goldratt Marketing Group.

Goldratt, E.M. 2011. *Now and in the future seminar: Closing remarks* October 15; Available from: https://www.youtube.com/watch?v=E6GegcyUqBY&feature=youtu.be.

Goldratt, E.M. 2011. *Science of management*. (video)2011 (cited 2017; Available from: https://www.youttube.com/watch?v=BZcwXENrZnA&feature=youtu.be.

Goldratt, E.M. and J. Cox, 1984. *The Goal: Excellence in Manufacturing*. First ed. Croton-on-Hudson, NY: North River Press Inc. 262.

Kaizen, 2008. in *Kojien Dictionary*.

Kishira, Y. 2014. *Personal communication with Shinya Yamanaka*, S. Yamanaka, April.

Kishira, Y. 2014. *Three tools for thinking clearly*. Tokyo, JP: Diamond Inc.

Kishira, Y. *How to learn the lessons from the failures in TOC way - "mystery analysis" - 7 questions with a case study*. in *TOCICO International Conference: 14th Annual Worldwide Gathering of TOC Professionals*. 2016. Leesburg, VA: Theory of Constraints International Certification Organization.

Noe, K. 2015. *Invitation to philosophy of science*. Tokyo, JP: Chikumashobo Ltd.

Popper, K. 1957. *Science: Conjectures and refutations*, in *British Philosophy in Mid-Century*, C.A. Mace, Editor. Allen and Unwin: London.

Scheinkopf, L.J. 1999. *Thinking for a change: Putting the TOC thinking processes to use*. St. Lucie Press/APICS series on constraints management. Boca Raton, FL: St. Lucie Press. xiv, 255.

Shinmura, I. 1998. *Kojien Dictionary*, in *Koujien Dictionary*. Iwanami Shoten: Tokyo, Japan.

Shinmura, I. 2008. *Kojien Dictionary*, in *KoujienDictionar*. Iwanami Shoten: Tokyo, Japan.

Suerken, K. 2017. *TOC for Education*. cited 2017 November.

System, in *Oxford English Dictionary*. 2017, Oxford University Press: Oxford, Eng.

Tobita, K. 2014. *Quality improvement without improving quality - How to use TOC to create breakthrough in the Gemba where kaizen/5S efforts are showing diminishing returns*. in *TOCICO International Conference: 12th Annual Worldwide Gathering of TOC Professionals*.. Washington, DC: Theory of Constraints International Certification Organization.

*TOC for Education, Inc.*2017 (cited 2017 November 12); Available from: http://www.tocforeducation.com/.

Yasuda, E. and M. Tobita. 2016. *How to make ordinary people achieve extraordinary performance - TOCfE Japan now and into future*. in *TOCICO International Conference: 14th Annual Worldwide Gathering of TOC Professionals*. Leesburg, VA: Theory of Constraints International Certification Organization.

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