TRIZ-ISHIKAWA diagram, a new tool for detecting influencing factors: a case study in HVAC business.

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Abstract

Eliminating an undesirable effect or reducing the gap between the desired situation and the actual situation, becomes a necessity for a performing organization. The Ishikawa diagram is one of the important tools that organizations use to find factors generating an effect. However, authors are still searching for the most convenient form of the diagram and still looking for generic cornerstones. This paper aims to integrate TRIZ into the Ishikawa diagram to overcome the diagram's actual limitations. The case study demonstrates the effectiveness of TRIZ-Ishikawa diagram. The new diagram will enable users to overcome psychological inertia and systematically identify influencing factors.

Keywords
Ishikawa diagram, TRIZ, Resources, HVAC, Problem solving.

1. Introduction
Organizations need to overcome daily problems to sustain their performance and competitiveness. Eliminating the problem or the effect is related to finding the root cause. Ishikawa diagram is one of the most relevant tools for analyzing problems and finding the main reason for a problem's existence. Many authors used the diagram to prevent or solve manufacturing and service effects (Suárez-Barraza and Rodriguez 2019). Others use the diagram to solve supply chain problems (Elleuch & al. 2016). While some research focus on medical issues (Ma & al. 2019; Kudla &

Brook 2018). The diagram has proven to be used in many fields. However, Ishikawa diagram have some limitations. In fact, finding the root cause and associating cornerstones is still difficult. Furthermore, at the end of the brainstorming, there may be no cornerstone to express the potential cause. Some research tried to standardize cornerstones as 6M or 4P (Koripadu & Subbaiah 2014). In addition, Suárez-Barraza & Rodriguez (2019), and Wong & al. (2016) were rare authors that critics the method and attempt to develop it. Based on their studies, the literature review, and the authors' experience, this paper tries to remove Ishikawa's barriers. First, we present the correlation between the 5M and TRIZ resources. Then, using resources strength, we propose an improved diagram that we test to reduce accumulated inventory in the HVAC business. Finally, we discuss the result and present the research limitations and future opportunities for the TRIZ-Ishikawa diagram.

2. Literature Review

2.1 Ishikawa diagram

Ishikawa Diagram Known also as cause-and-effect diagram (CE), or fishbone diagram is one of the seven basic quality control tools (Suárez-Barraza and Rodriguez 2019). Professor Ishikawa and his team used the diagram during the 1952-53 periods to structure factors in their research work (Suárez-Barraza and Rodriguez 2019).The classical definition of the diagram relates the Ishikawa diagram to the identification of variation factors as a cause of an effect. Whenever a problem is detected, it is essential to detail all the potential causes of the variation (Suárez-Barraza and Rodriguez 2019). Ma & al. (2020) defines Ishikawa as a tool that helps users to visualize and illustrate the complexity of the problem and shows how multiple factors can contribute to the effect. Hola & al. (2017) acknowledges that a specific effect depends on many factors that can be divided into groups. Kudla and Brook (2018) adds that the diagram recognize and inspect contributing factors to an undesirable event or inefficient process. Dobrusskin (2015) defines the Ishikawa diagram as a standardized way to conduct efficient investigations. We conclude using those definitions that the Ishikawa diagram is a standardized tool that helps users to extract and identify contributing factors to a specific effect. The identified factors are divided into categories or cornerstones. We need to highlight that, in the original version; the cornerstone was defined according to the problem or effect context. Then, next to each cornerstone, we define factors that may influence the effect. For example, Kudla and Brook (2018) chooses Pathology, process, policies and practice, Equipment, environment, and people as cornerstones for near-miss interpretive errors. Ma & al. (2020) defines organization, equipment, providers, and people as cornerstones for communication issues. Moreover, Simanova and Gejdos (2015), choose four groups which are: input material, working conditions, service equipment and employee to reduce disagreements.

Nowadays, the new version includes the 5M acronym of Machinery, Manpower, Material, measurement, and method (Suárez-Barraza and Rodriguez 2019). Other authors add Management (Dobrusskin 2015) Method, and environment (Hola & al. 2017).Moreover, Koripadu and Subbaiah (2014) categorizes the 6M (Machine, Method, Material, measurement, Mother Nature, and manpower) for manufacturing industries and 4Ps acronym of policies, procedure, people and plant as the diagram branches for service industries.

Another aspect of the diagram is asking "why" for each cause-and-effect relation. The objective is to put the "why" question for each cause at the primary level. Then, the "Why" question is repeated for each level until reaching the root cause. At the end, we choose the appropriate causes that have a direct impact on the studied problem.

The Ishikawa diagram proved its efficiency in many fields; industry, Medicine, Services, supply chain, and education (Suárez-Barraza and Rodriguez 2019). It may be used to correct or to prevent an effect, it offers benefits for users such as:

- Systemizes the analysis step (Suárez-Barraza and Rodriguez 2019; Wong & al. 2016).
- 5M or 4P facilitates the use of cornerstones as guidelines for gathering information. (Koripadu and Subbaiah 2014)
- Present a variety of potential causes, and diversify ideas (Wong & al. 2016)
- Visual classification that can be used for further investigation (Wong & al. 2016)

Unfortunately, this approach can present many barriers such as:

- Difficulty to relate some causes to a particular category.
- Potential bias (Culture, motivation, personality, and the team) may affect the result.
- The Manpower factor is usually misunderstood. The fear of being personally attacked or accused by the problem presents a natural barrier.

- The Time and the system evolution is missing in the diagram
- The need for more factors to adapt the diagram to the effect.
- There may no cornerstone proposed to explain the cause of an effect.

Questions that arise are: How can we improve the diagram limitations and lead users to find the root cause easily? Knowing that resources are cause of problems, how can we use them to create a new diagram?

2.2 5M factors and TRIZ resources assessment

Mann (2002) and Mueller (2005) formulate resources as anything, in or around, the studied system. They have direct effects on the problem. Mueller (2005) presented an elementary level to define resources as presented in table 1. Besides, we present the correlation between the 5M and resources. Mueller (2005) synthesize TRIZ preliminary resources in six categories, which are Substances, Field, functional, informational, time and spatial.

Table 1. Resources description according to Sandra Mueller and the correlation with 5M.

Resources in Management TRIZ		Machinery (technology)	Manpower (physical work)	Material (raw material)	Measurement /inspection / environment	method (process)
Substances	● Studied system elements. ● System's environment (Material, Machines, products and humans)	X	X	X		
Fields (Interactions)	● Between system elements and/or within a system (e.g., communication; energy) ● From a system's environment (e.g., competition, electricity, transition system) ● Between systems (e.g., network) ● Reserves (utilization of substance full potential.(e.g., enthusiasm) ● defeat (e.g., anger, Power)	X	X	X		X
Functional	● Gaps in a function ● Application of harmful factors ● Exploit casual ● provided functions ● Additional useful functions	X	X	X	X	X
Informational	● Emitted/transmitted information from the system and its elements ● Intrinsic properties of the system and its elements. explicit and implicit knowledge (e.g., behavior or inherent information such as efficiency, availability, transparency, shape) ● Temporary information (e.g. date) ● Information flow. ● information change	X	X	X		X

Time	● Time before the procedure starts (e.g., preliminary work) ● Time during a process: Parallel work, Pauses; anticipation. ● Post-process time ● Scheduled work ● Temporary actions ● velocity ● period					
Space	● Unoccupied space ● Space between elements; Space inside parts; empty surface of element. ● Space occupied by unnecessary elements. ● Space available in another dimension ● Another display ● Foreside/backside ● outline, surface				X	

Authors, Adopted from Sandra Mueller (2005)

In TRIZ definition, substances may refer to the studied system elements or the system's environment. It submits Materiel, Manpower, and Machines. Moreover, Fields present the interaction between systems. It describes the energy and the interaction in the system or between the system and substances. In addition, functional resources show the methodology of how substances are used according to basic needs. The informational resource helps to understand the non-detection causes. It also shows inherent proprieties of the system and substances, including data, knowledge, behaviors, and communication systems. Additionally, space refers to space between elements, space occupied by substances, or external factors like temperatures, pressure, or light. Eventually, Time expresses any kind of time, including time intervals, duration, and the system within substances evolution. It describes the Time before the problem starts and during the problem. It also may illustrate time organization, habits, or temporary actions.

TRIZ resources support solvers in explaining predominantly technical or managerial problems. The main advantage is when we extract substances around the studied problem. For example, if we want to study signature variation cause for the same person, substances are the hand, the pen, the paper, and the paper support. Variation causes are related to those substances. The energy of a substance or between substances may have an impact on the problem. For or example energy to maintain the pen by the person or stabilization of the paper support may have an impact on the signature variation. In addition, functionalities of the substance, as the hand speed, the pen functionality, or the paper proprieties may influence the signature. In time resource, substance description during time can reveal some variation causes.

We conclude, as presented in table 1 that there is an implication between 5M and resources. Moreover, Time is not well explored in 5M. We detect also that resources can describe a detailed and large spectrum around the studied system. It will have better and structured guidelines for solvers.

3. The methodology and case study

3.1 TRIZ-Ishikawa diagram

Using this correlation, we propose, in figure 1, the TRIZ-ISHIKAWA diagram as an improved analyze tool to detect influencing factors. To complete the diagram first, we need to place on the right side of the diagram the studied effect. Then, the team lists substances concerning the studied subject. The objective here is to have a global vision of the system and its context. Then, in the Time factor, the team describes substance during Time. By enumerating substance evolution, solvers may detect immediately potential cause. Finally, Space, field, Functional, and Informational resources are discussed to extract other influencing factors.

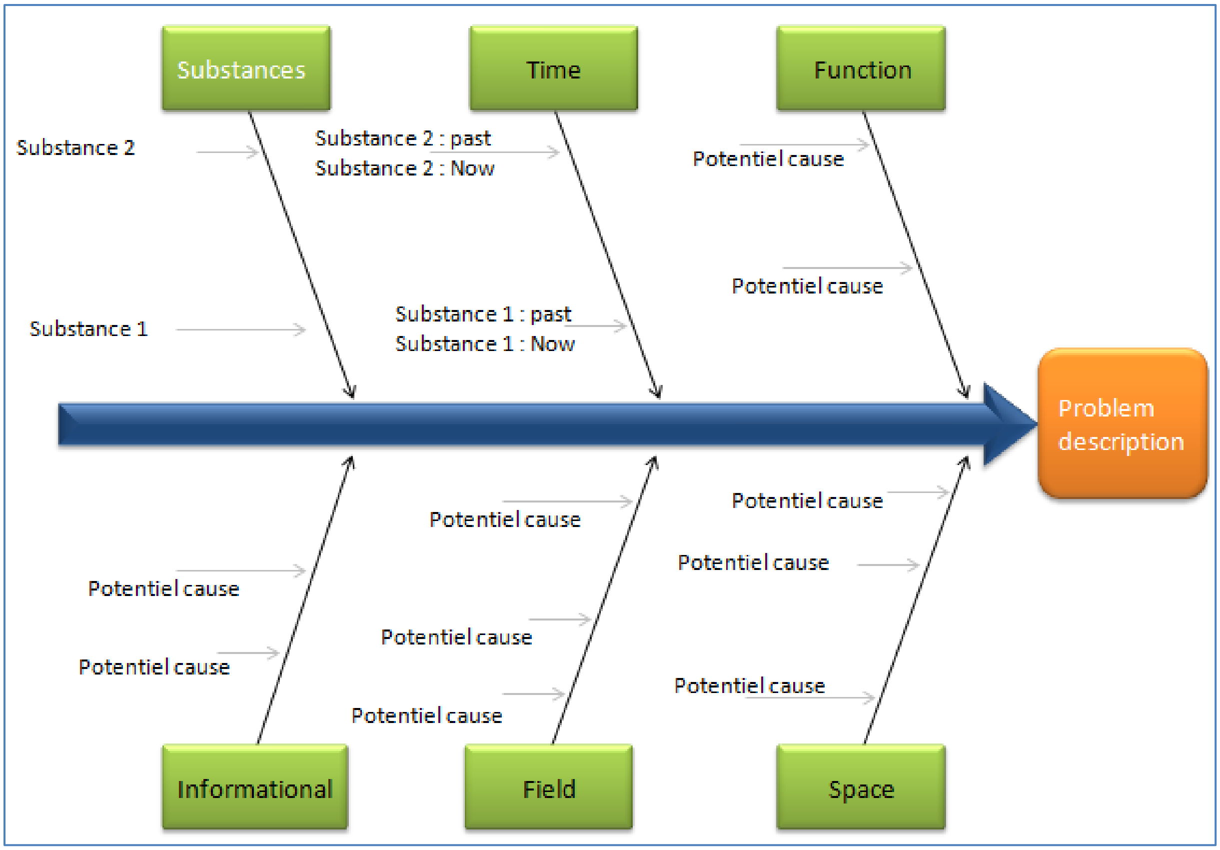

Figure 1. TRIZ-ISHIKAWA Diagram

The classic Ishikawa diagram is based on hazardous method to collect potential causes (wong2016). However, enumerating substance around the studied system, helps users to focus on a small spectrum of potential causes. The root cause is for sure one of the listed factors. In addition, the diagram conception eliminates the need for other cornerstones to complete the diagram.

3.2 The case study:

In an HVAC Company, the accumulation of inventory is a serious issue. First, it occupies an important storage space because of the material volume, and it blocks capitals. The generation of inventory can be caused by many factors.

The studied HVAC Company works in air conditioning projects. They are called to study and propose the aeraulic system and to install piping and air conditioning systems according to the customer requirements, and control specifications. At the end of projects, the company observes the raw material accumulation. To detect factors influencing raw material accumulation we use the TRIZ-Ishikawa diagram as presented in figure 2.

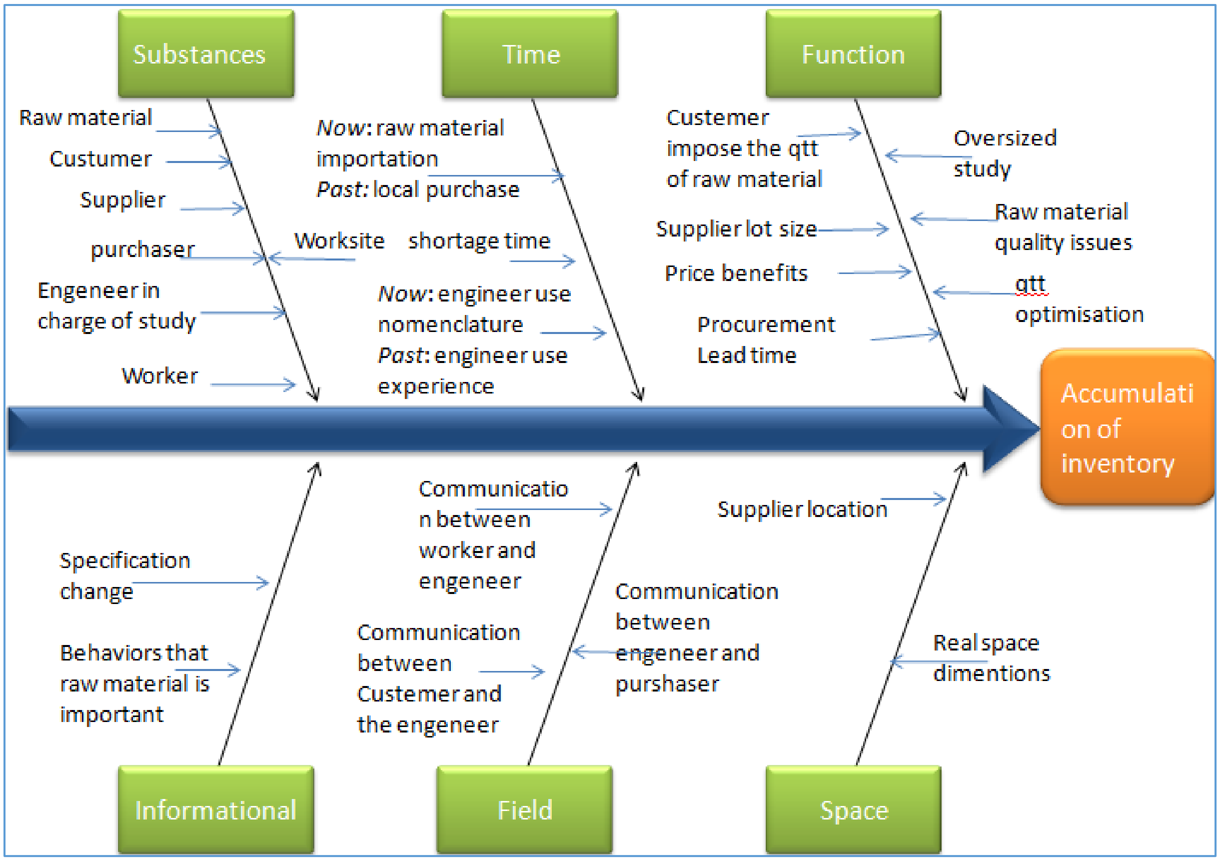

Figure 2. TRIZ- Ishikawa diagram applied to the accumulation of inventory

The accumulation of inventory is due to many factors. Any person in the study process, procurement chain, or operations may influence the inventory. In addition, supplier conditions, customer requirements, and even the storage place may influence the inventory value. Furthermore, engineers use a new procedure to list component for procurement and import them directly from sources. As well, behaviors, the company's culture, communication between actors and storage space will influence the inventory.

In this case, we observe that the accumulation of inventory does not depend only on the purchaser or worker but depend on the chain, from defining the project specification by the customer, to the project closing. To detect the root cause, we need to complement the study with investigations. We may have one or more influencing factors depending on the context.

4. Result and discussion

According to the review, Ishikawa diagram present limitations to have accurate data. In fact, users still have difficulties to relate some cause to a particular category, they need more factors to adapt the diagram to the effect and there may no cornerstone proposed to explain the cause of an effect. Some authors add other factors to adapt the diagram to the studied situation. As resource and evolution systems are used to analyze issues in TRIZ philosophy, we integrate them into the Ishikawa diagram.

The TRIZ-Ishikawa is the improved version of the Ishikawa diagram. It allows detecting all substances that may influence the problem. The evolution system can help to detect some changes that happen in the system or around the system. Then substance functionalities, the energy between substance and the studied problem, information, and the space are guidelines factors to detect others influencing factors. The TRIZ-Ishikawa can open psychological inertia and eliminate resistance because we are not just inventorying the cause factors directly, but we are inventorying substance around the studied system that may have an influencing impact on the studied effect.

The case study shows that the diagram can be used in supply chain issues, and it presents an exhaustive potential causes list. However, in further research, we need to test the diagram in other filed to prove its efficiency.

5. Conclusion

The TRIZ-Ishikawa diagram is an improved version to detect contributing factors to a specific effect. It presents guidelines for users in the brainstorming process and surmounts the classical Ishikawa diagram barriers. Substance inventory helps users to overcome psychological inertia and the time pillar integrates the evolution system concept in the diagram. Using TRIZ resources as cornerstones avoids the need to add more cornerstones.

In addition, we are aware that a unique case study does not allow diagram generalization. Therefore, it is necessary, in future research, to explore the diagram in a different field with different issues.

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