Clustered Model TRIZ and Application in Industries

Nagappan Annamalai, Shahrul Kamaruddin, Ishak Abdul Azid, and T. S. Yeoh

***Abstract*—The paper shares the research on applying a clustered model Theory Of Inventive Problem Solving (TRIZ) and suggests how this is impactful to industries with a case study sharing from a development practices. The paper also briefly educates how TRIZ and LEAN methodology via Define-Measure-Analyze-Improve-Control (DMAIC) has helped to resolve a real industrial case study. What-Why Analysis model is being used in this case study, which gives clear amplification of the importance of solving the problem. The example is mainly an application in industries, identifying and to overcome a long preventive maintenance problems that are costly and redundant.**

***Index Terms*—Problem solving, Model TRIZ, industries, methodology.**

I. Introduction

In recent years, there has been a growing interest in the link between problem-solving capabilities and applications in industries and development performance. The industry mission is to be the clear choice on affordable technology and manufacturing. The company business uses numerous problem solving methods to achieve operational excellence. In this article, the authors in research on applying a clustered model TRIZ and suggest how this is impactful to industries with a case study sharing.

The problem-solving approach, popular in many tertiary institutions and with an emphasis on solving structured, well defined problems using standardized techniques, may be traced to 'hard" systems thinking [1]. The creative design approach, on the other hand, combines analytical and systems thinking with human factors in engineering design to create and take advantage of opportunities to serve society.

In a dynamic environment like industries, where the state of the domain is constantly changing and evolving, problem solving involves the transformation from one temporal stage to another stage, which is normally caused by an event or a chain reaction event [2]. It is impossible to model all conceivable internal and external events that may cause changes in the problem domain. Therefore, clustered modeling can be used as an aid for considering the situation, generalize the plan, making decision, and obtaining the results of problem solving that we have done.

During the process of problem solving, the solution to problems is always generated by a detailed process analysis or at times based on knowledge acquired from past experience and extended to fit to new situations. This is where TRIZ comes in the way of 40 inventive principles which were mined from tons of patents in the past. Depending on the nature of problem, different inventive principle can play its role in aiding the problem solution.

When a new problem is being defined, initial state of problem solving is to assess the current situation through a process analysis, and to identify a desired situation where the problem can be solved. At times the distance between the current state and desired state is vague with some uncertainty with containment actions or also known as intermediate state.

II. Methodology

A. TRIZ

Problem solving process is the search for the innovative and creative solution. There are several ways to solve industrial problems during development of product, and manufacturing processes [3]. Genrich Altshuller (born in 1926 in former Soviet Union) served as a Navy patent engineer in the 1940's to support the patenting of inventions. Altshuller created the Theory of Inventive Problem Solving (known as TRIZ). The method was based on study of more than million patents worldwide [4]. Furthermore this method shows that the existing intuitive method did not meet the requirement for inventions in the 2nd half of 20th century.

TRIZ is a type of method filled with innovative theory that works by solving the contradiction [5], [6]. Based on the evolution of technical system and the levels of inventions, the methodology is composed of various types of methods, tools, calculation for solving technical problem and providing innovative exploration [7]. Furthermore, TRIZ has been applied to different fields of knowledge [5], [8], [9].

In addition, TRIZ methodology (Fig. 1) uses concept and tools that provide systematic approach and general principles for analyzing and modeling problems and engendering creative ideas, and forecasting evolution trends of a system [5], [10].

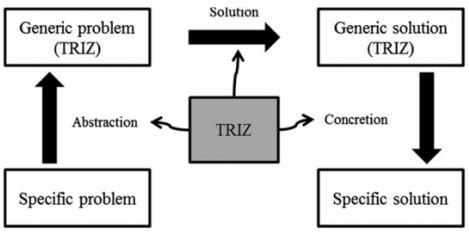

Fig. 1. TRIZ methodology.

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Large industries such as Procter & Gamble, Ford Motor, Boeing, Philips, Samsung, Intel, and LG have used TRIZ [11]. To understand TRIZ methodology, it is important to have a clear understanding of its fundamental concepts.

The process analysis framework was important for industrial studies. The technical details were used to apply the research by conducting data analysis, measuring unwanted functions at the process steps, and subsequently calculating the estimated losses. After selecting the critical processes, a functional analysis is conducted to map all occurring interactions. Thus the useful and harmful functions were exposed.

The finding of evolved Model TRIZ proposed to perform What & Why Analysis [12], which will give clear amplification of the importance of solving the problem. Hence determined the reason behind the cause of stopping the team to solve the problem intially.

B. DMAIC

The DMAIC (Define-Measure-Analyze-Improve-Control) method (Fig. 2) in Six Sigma is often described as an approach for problem solving. Six Sigma is defined as an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reduction in customer defined defect rates [13]. DMAIC is similar in function as its predecessors in manufacturing problem solving, such as Plan-Do-Check-Act and the seven step method of Juran & Gryna [14].

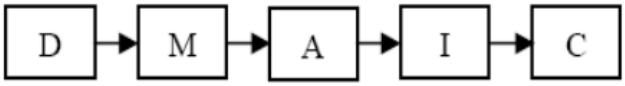

Fig. 2. DMAIC phases.

Six Sigma and its DMAIC method clustered and developed in practice. It built on insights from the quality engineering field, incorporating ideas from the quality control, total quality management and Taguchi's offline quality control. Their wide adoption in practice warrants a critical scientific analysis. Once aspect of a scientific evaluation of Six Sigma is critically compared, its principles with insights from established scientific theories [15].

Six sigma's DMAIC method is a rather general method. Its original task domain was variation reduction, especially in manufacturing process. Later the method was used for general task, such as quality improvement, efficiency improvement, and beyond manufacturing in services, and other operation.

C. Clustered Problem Solving

Problem solving has been studied extensively in the OR/MS/IE literature. Following the definition given to understand a problem as a choice of situation in which a person attaches negative value to the current state of affairs, and is in doubt which course of action to take [16]. Problem comes in wide variety of type. The problem solving literature offers various stepwise models for problem solving process such as:

- Obsorn-Parne a creative problem solving model: Mess finding; fact finding; problem finding; idea finding; solution finding; acceptance finding
- March & Simon [17]: Problem identification; Diagnosis; Solution generation; implementation
- [17]: Problem Definition; Problem Analysis; Generation and selection of solution; testing and evaluation; optimization
- DMAIC [15]: Define Problem; Measure; Analyze; Improve; Control
- TRIZ [5]: Problem Definition; Problem Analysis; Contradiction & Innovative Solution

Six Sigma does not offer much flexibility in dealing with the large diversity of real-life problems and the task that they imply, and DMAIC claimed to be unsuited especially for problems of limited task content [15]. Kepner Tregeo's rational process [18] is an example of a somewhat more flexible system. It offers 3 methods intended for specific problem type (problem analysis, decision analysis, and potential problem and opportunity analysis – hypothesis).

Diagnosing a problem, is a process involving a repeated alteration of hypothesis generation, the identification of candidate causal explanations, and hypothesis testing. Hypothesis generation is driven by observation and findings on the one hand, and reasoning from domain knowledge on the other. Domain knowledge addressing diagnosis typically includes models of the physical structure of the system under study, such as a breakdown into its components and parts, and functional model (TRIZ), which represents how the system or process works [19].

The efficiency of diagnostic process depends on the search strategy, which sequences diagnostic task such as hypothesis generation, testing and creation or explore domain knowledge [20]. The study provides a Characterization of the types of problems for which DMAIC Is a suitable method, but also identifies Problems for which it may be ineffective. An important limitation of the method is its generality, which limits the methodological support it provides, and which fails to exploit task-domain specific knowledge. Domain-specific adaptations of the Method partly over comes these weaknesses. Among the method's strengths are the powerful statistical techniques for fact finding and empirical verification of ideas, and the DMAIC stage model, which acts as a problem structuring device.

The most prominent limitation identified in this study is Six Sigma's inferior methodology for efficient problem diagnosis and solution findings, which TRIZ plays strong model integration.

TRIZ is a knowledge-based systematic methodology of inventive problem solving [21]. TRIZ as a methodology for the effective development of new technical systems [22], in addition to it being a set of principles that describe how technologies and systems evolve. Also, it has been described [23] as a toolkit consisting of methods which cover all aspects of problem understanding and solving. This toolkit is regarded by some as the most comprehensive, systematically organised for invention and creative thinking methodology known to man [24]. TRIZ rests on the premise that technology evolution and the way to invention is not a random process, but is predictable and governed by certain laws [25], [26]. It is on analytical logic and a systematic way of thinking [21], [25]. This systematic approach provides an

overall structure for the application of the collection of TRIZ tools and techniques.

DMAIC and TRIZ are widely being used in industries, from the ways of solving the technical problems and also process optimizations related. TRIZ is very much well known to give high impact on innovative solution space vs. DMAIC more on process analysis. The sequential of this will bring a clustered modeling, where modeled TRIZ and DMAIC approach is being utilized to solve one of the industrial issues. A case study will be shared on the approach how this 2 problem solving tools has clustered make it beneficial to industrial field on optimizing PM (preventive maintenance).

III. Case Study: Industrial Approach

The company mission is to be clear choice for affordable technology and manufacturing. Its strategies goes with maintaining the technology leadership, deliver manufacturing excellence, exceed customer expectation, be the work place of choice and relentlessly pursue shareholder value [12]. The objective would be delivering leading edge technology at affordable cost, be perceived as the cost leader in manufacturing, and exceeds the customer quality, responsiveness and the product performance expectations. The company businesses use numerous problem solving methods to achieve operational excellence.

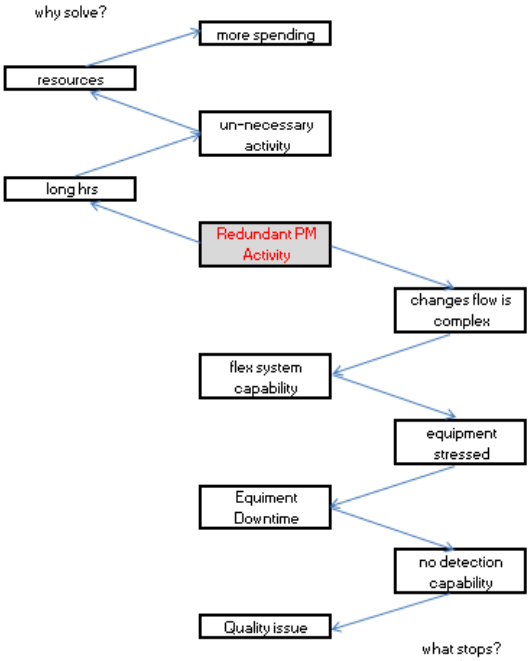

Fig. 3. Why-What analysis.

There are 3 key stages in clustered model TRIZ methodology. Stage 1 problem definition – at this stage the problem statement is reviewed to have a better understanding of the issue. According to Kettering the head of research for General Motors stated "a problem well stated is a problem half solved" [27], [28]. Findings [12] from evolved Model TRIZ proposed to perform What & Why Analysis (Fig. 3), which will give clear amplification of the importance of solving the problem. Hence determined the reason behind the cause of stopping the team to solve the problem initially. The fact is, generally from the observations; the grounds of this circumstances happening is eventually reflected from the distance between the problem statement and the segmentation. It is often not been bridged correctly that end-up focusing on inaccurate issues thus resulting into providing non-optimal solutions.

In this section it will detail out on the clustered model TRIZ with DMAIC methodology and modeling development. The model will then be validated through case studies; to address the long hours and frequent PM activities. The case study research is one of the most powerful research methods in operational management, particularly in development of new methodology [29]. A manufacturing case study have been identified and presented to show the clustered model TRIZ model being adopted for resolving critical process related issues within a four month time frame. The key problem of the case is 4 folds; first relating to productivity, followed by space, safety and quality problem faced by an equipment type.

Preventive maintenance is a routine activity to ensure system stability. A sequential activity carried out on the equipment to ensure the stability and health is being sustained. PM elements consist of, maintaining the normal operation condition of equipment, followed by master scheduled PM. What is the current industrial practice? The PM performed is based on interval of time range which is known as time based PM (TBPM). The case study explored was referring to PM activity which consists of long hour activity through frequent time range, and does this benefit? Obviously the answer is no, as high wastage will be observed for non-constrained equipment's. How do we go about to achieve this kind of problem?

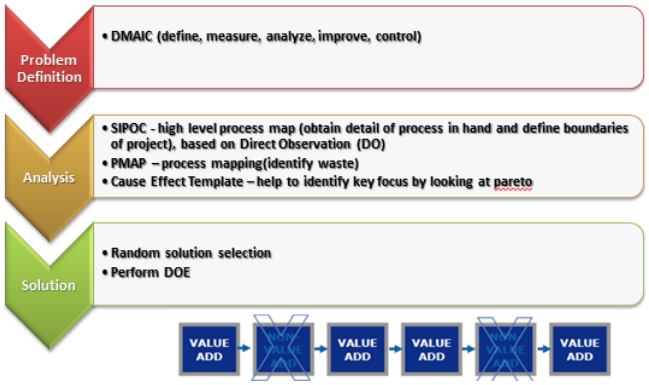

Fig. 4. DMAIC toolkit.

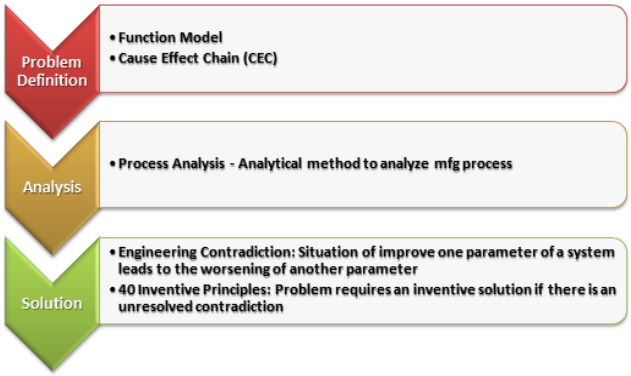

Fig. 5. TRIZ toolkit.

This is where clustered model TRIZ approach with

DMAIC is being analyzed. Lean Six Sigma focuses on process related issue. It is a powerful tool to identify waste, which needs to be efficiently eliminated. It consists of DMAIC on problem definition together with analysis through SIPOC which is a high level process mapping based on direct observation (DO). This is not so impactful or efficient in solution space and random idea generated through design of experiments (Fig. 4). TRIZ on the other hand is a very powerful tool for solution space and detailed out problem definition through function analysis and cause effect chain (CEC) (Fig. 5). Although we are talking about process analysis but it is not as specific and detailed as supplier-input-process-outputs-customers (SIPOC). SIPOC is used when planning to start process management of improvement activities [30]. It is important to het a high level understanding of scope of process first. A SIPOC process definition helps the process owner and the working on the process to agree the boundaries of what will be worked on. It provides a structured was to discuss the process and het consensus on what it involves before rushing off and drawing the process mapping. Clustered model TRIZ is being evolved through SIPOC and DO (Fig. 6) at the stage of process analysis, mainly to trim the identified waste (waste management)

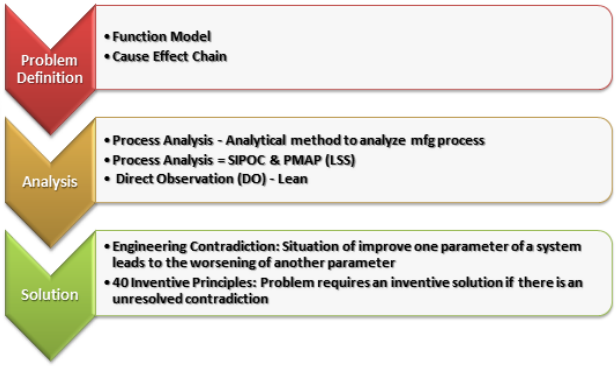

Fig. 6. Clustered TRIZ (DMAIC and TRIZ compliments).

Stage 2, process analysis details out the manufacturing process through SIPOC and process mapping (PMAP) (Fig. 7). Process map is a graphical representation of a process that provides the detailed process steps, and the relations. The key one is that it also details out whether the steps are value add or non value add through DO activity. The effort of creating a detailed process map is to refine the focus to the process steps that create the biggest problem or highest defect rate.

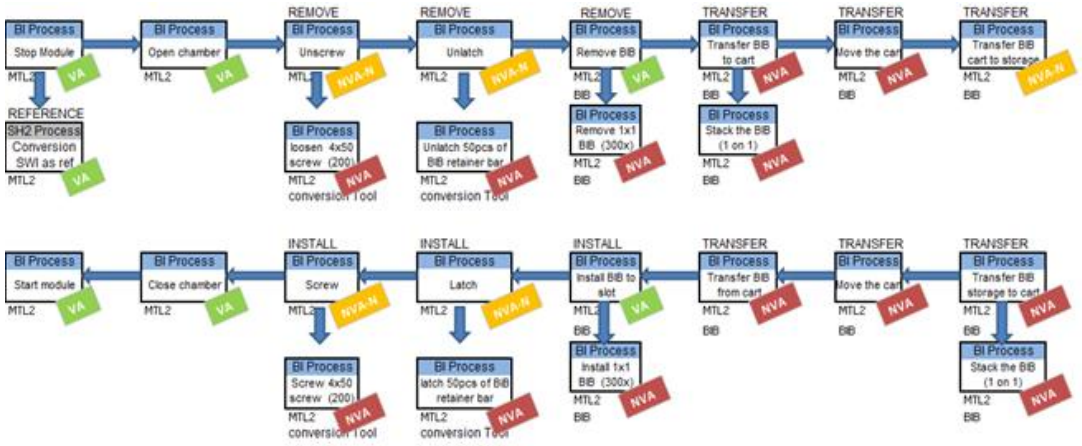

Fig. 7. Process mapping.

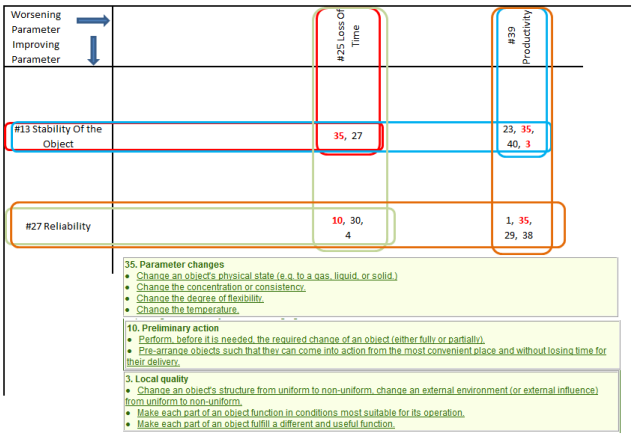

Fig. 8. Contradiction matrix 1.

Stage 3, solution space, which comes with contradiction statement to work within the 39 system parameters of TRIZ, which would lead to 40 Inventive Principles. "IF frequent scheduled PM is performed on equipment THEN the equipment is stable for the specific duration BUT it will consume high resorce (impact time and productivity) for PM activity". Below (Fig. 8) shows how the 39 parameter table narrows to a potential of 3 inventive principles to solve the contradiction.

The solution came about through principle#35 which would be parameter change. How? The frequency of the PM can be potentially changed from time based (TBPM) to a volume base (VBPM). This would enable the frequency of PM to depend on the volume run on the equipment which would reduce the occurance of PM activity on the specific equipment.

But there was another contradiction where some tools stay with long idling with long PM frequency. This may potentially impact a hard down as the PM was not carried out for a long duration. Equipment stability would lead to a risk and end up with potential quality issues. Another contradiction statement came about; "IF PM done based on volume THEN equipment availability will improve BUT equipment unstable as PM activity too far apart due to low volume". Below (Fig. 9), reflect contradiction matrix 2 for the 2nd engineering contradiction.

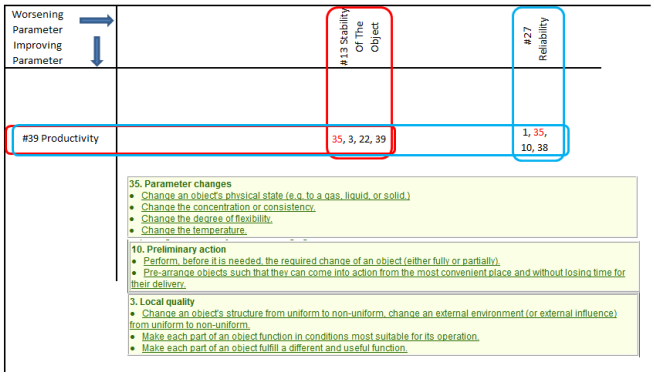

Fig. 9. Contradiction matrix 2.

Here principle#10 which is preliminary action predifine the TBPM as a gate and check for VB factor on the equipment utilization across time. A monitoring tool will be a triggering system. Follow by principle#3 which is local quality reflects the change in PM model from scheduled to a non uniform PM model. Make use of exisitng system fully. This enable a new paradigm change called Hybrid Based PM (HBPM). The solution concept would be which ever comes 1st either the volume or time. The PM system will function as more reliable and independently with a non uniform manner.

IV. Conclusion

In general, it is concluded that TRIZ can be clustered with DMAIC or any other problem solving methodology on improving the industrial problems and processes. The concept and tools in the studied sector (semiconductor) were effective for developing clustered model TRIZ opportunities because the solution was attractive technically, and economically. In addition these solutions demonstrated the feasibility of including the environment in semiconductor process without financial or technical losses.

Process analysis through clustered model TRIZ was effectively described in the studied problems and maybe become an alternative future industrial approach. The use of function analysis is promising in companies that lack available data and information. When data is lacking, the system must be disrupted to perform the necessary study. However the initiation of the pilot projects may become an option to conduct the preliminary evaluation of clustered model TRIZ approach. Moreover this approach allows for detailed studies regarding the clustering the process analysis between 2 different methodologies and also problem characterization and segmentation, and its contribution to the development of inventive solutions.

The conclusion here, that clustered model TRIZ can effectively find options for lean manufacturing and direct us towards near ideal solutions. In general all the proposals have the potential to be replicated in similar industries because they are beneficial with minimal investment and ease of applications. In addition, the proposed solution on the case study shared can provide competitive advantages for all the industries on the preventive maintenance processes. These advantages can allow for more available time and spare consumption reduction along with technical resource alignment to industries at all strategic level.

We suggest that further research to be conducted in other fields of industries. The research would identify more opportunities and enhance the clustered model TRIZ approach.

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