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INTEGRATION OF VALUE ENGINEERING AND TRIZ-THEORY OF INVENTIVE PROBLEM SOLVING: A THEORETICAL FRAMEWORK IN MALAYSIAN AUTOMOTIVE INDUSTRY

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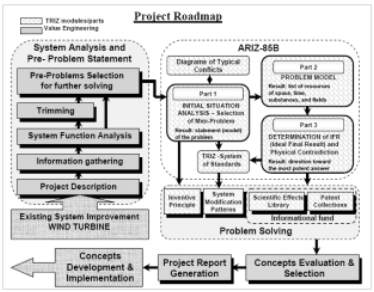
Graphical abstract



Abstract

The paper aims to suggest a theoretical framework that demonstrates the integration of Value Engineering (VE) procedure with Theory of Inventive Problem Solving (TRIZ) tools, systematically tailored for Malaysian automotive environment. Previous works on VE-TRIZ integration are base on the SAVE® guidelines named Value Standard flow that suggested various TRIZ integration or entry points throughout this flow. However, in this work, the integration will take effect into the *Creative Phase* of the Value Standard flow. TRIZ is still new in Malaysian industrial perspective while as VE has become an accepted procedure in cost reduction activity in various industries especially in construction sectors. Referring to automotive industry, VE implementation is seen ineffective since the overall and complete VE concepts and procedures are not thoroughly well-understood and applied. To balance the above-mentioned issues and to catalyst the effectiveness and successful of VE-TRIZ implementation specifically in the context of automotive industry, the proposed theoretical framework is seen inevitably beneficial.

Keywords: Value engineering, value analysis, TRIZ

Abstrak

Gabungan konsep Kejuruteraan Nilai dan TRIZ dicadangkan bagi menambah baik perancangan pengurangan kos terutama melibatkan komponen kenderaan di Malaysia. Ini mengambil kira senario tempatan di mana penggunaan Kejuruteraan Nilai dan TRIZ masih baharu menyebabkan konsep ini tidak difahami dan pengurusan kos tidak dapat memenuhi potensi sepatutnya. Cadangan penambahbaikan ini tertumpu ke bahagian Fasa Kreatif didalam Standard Nilai (merujuk kepada rancangan pengurangan nilai SAVE®). Rangka kerja baharu yang mengabungkan Kejuruteraan Nilai dan TRIZ dicadangkan bagi memenuhi senario automotif tempatan.

Kata kunci: Kejuruteraan nilai, analisis nilai, TRIZ

1.0 INTRODUCTION

Currently, VE methodology is broadly accepted especially in the construction eco-system, as a function improvement and cost reduction tools that increase the product, process or project values without jeopardizing quality. Brainstorming technique has been the main tool for VE's idea generation but it

has some limitations [1]. In the attempt to enhance brainstorming effectiveness, studies were done to integrate VE with a TRIZ structured inventive tools.

This study is done to identify alternative methods in enhancing VE activity. Limited numbers of automotive organizations (both OEMs and component manufacturers) use VE as cost reduction tools without understanding VE. Aliza.R, Suzanna.S and F.Mitchel in their research discovered that no proper VE tools were used in all VE activities in their case study organization [2]. These organizations merely use benchmark and component teardown techniques without knowing the existent of a structured VE processes promoted by SAVE® [3]

For this, VE-TRIZ integration is being explored concentrating on the VE's *Creative Phase* (i.e. *Idea generation phase*) and the propose framework is presented in Fig. 3. The framework is based on the consideration that automotive OEMs and component manufactures are beginners to VE and TRIZ methods, hence specific TRIZ tools are introduce for easy understanding and application.

1.1 Value Engineering (VE)

Value Engineering (VE) is a systematic team-based approach created by Lawrence D. Miles of General Electric during WW2, used to improve the essential value of a product, system or service by reducing its costs and/or improving its function [3].

VE is a proven methodology with effective tools for cost reduction and improving value by analyzing and improving function of a subject. It referring to SAVE® systematic plan that follows *Value Job Plan*, a method applied by multidisciplinary team members to improve subject function and value. *Value Job Plan* follows six phases in sequence as shown in Table 1.

1.2 Theory of Inventive Problem Solving (TRIZ)

TRIZ is the acronym of Theory of Inventive Problem Solving in Russian roman alphabets. It is a theory of inventive problem solving founded in Russia 50 years ago by Genrich Altshuller. After studying more the 200,000 patents, he found that the same fundamental principles appeared repeatedly in inventions, and the most creative patents have embedded with solutions which satisfy contradiction requirement [4]. Altshuller then established a unique methodology to interpret and identify problems and provide probable solutions.

TRIZ suggests more then 20 tools for generating ideas and solving technical problems. Among them, contradiction matrix is one of early tools based on more than 40,000 patents analysis, and it is a strong method for deriving new concepts for products. Some concepts of TRIZ are similar to those of VE, for example, TRIZ's *Function Analysis* and VE's FAST diagram, concentrate on understanding subject performance through detail analyze of each components structure and function, but both methodologies represent their own strengths and weaknesses.

For example, VE is more universal in the application but TRIZ can generate more far-reaching solution of a problem [3]. TRIZ provides problem solving tools which VE's brainstorming technique is lacking and the integration of TRIZ into VE Value Job Plan can improve its effectiveness in suggesting solutions

Table 1 Value job plan [3]

VE Phase	Description
1. Information Phase	Review subject readiness, categorize subject function and identify project objectives and expectation.
2. Function Analysis Phase	Logically analyse subject functions and determine potential improvement on subject. Subject functions are structured into Function Analysis Systems Technique (FAST) diagram that serve as function mapping tools to aids in visualizing all functions in relation with subject components.
3. Creative Phase	Analyse and suggest alternatives way or process to perform the function. Brainstorming, ABC analysis, Gordon technique, Morphological analysis, Attribute listing and TRIZ are among techniques used as idea generation tools, but Brainstorming is normally used.
4. Evaluation Phase	Select potential solution for function and value improvement, replacement or elimination.
5. Development Phase	Further develop selected solution through detail consideration both technical and commercial (or financial implication).
6. Presentation Phase	Prepare report presenting problems, proposal, development program and cost analysis.

2.0 LITERATURE ON VE-TRIZ INTEGRATION

Previous works on VE-TRIZ integration were based on SAVE® Value Standard flow. Results of the current studies provide various integration points throughout the Value Standard flow. Even though majority of previous researches were concentrating on the *Creative Phase*, different frameworks suggestions were introduced to cover other phases within the *Value Job Plan*.

I. Bukhman and S. Brown studied on the improvement of wind turbine development using TRIZ with VE, for problem identification through their Project Roadmap as shown in Figure 1 [4]. They used VE-TRIZ at *Creative Phase*, and suggested ARIZ innovative technique to generate idea. ARIZ is Algorithm for Inventive Problem Solving, one of TRIZ's major analytic tools that provide step-by-step guidance one can follow in order to create innovation solutions. It can be applied to solve complex problems using a solution for which contradictions are difficult to be identified.

Though ARIZ is a comprehensive problem solving tools where other TRIZ tools (e.g. 40 Inventive Principles, Su-Field, Contradictions) are not capable of giving sound result, but it has limitation on its own.

With 85 steps to follow, it would be a tedious flow especially for those who are new to TRIZ. To assist, various ARIZ softwares (e.g. I-TRIZ-TRIZsoft, Guided Innovation Toolkit-GB TRIZ, TriSolver) were developed, and some studies were done to simplify these steps.

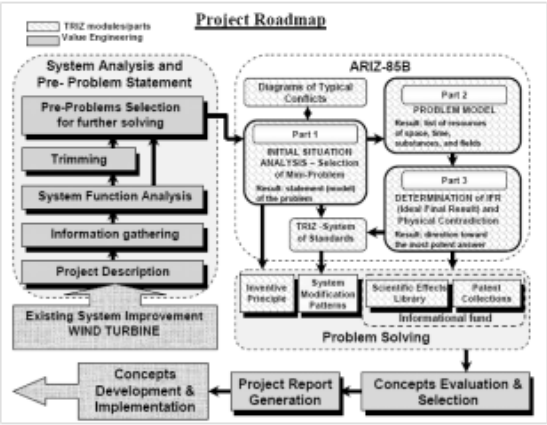


Figure 1 Project roadmap [4]

Dull C. B. in his work, modified *Value Job Plan* that included TRIZ technique. TRIZ was adopted in all VE phases except *Presentation Phase*. In *Information Phase*, he suggested the use of Innovation Situation Questionnaire (ISQ) to access the subject or condition for improvement, while Problem Formulator technique was used during *Function Analysis Phase* to identify positive function or negative or harmful function [1]. This was done since FAST diagram are not able to identify these responding functions.

In the *Creative Phase*, problems with contradiction issues are dealt first using TRIZ Contradiction Matrix, followed by the development of concept for innovation. While in *Evaluation* and *Development Phases*, he suggested of using TRIZ tool to overcome an unsolved problems or barrier exist on the most potential ideas suggested. Dull also suggested the cooperation of cross functional team of VE and TRIZ experts to rationalize problems and recommend solutions. This would be a challenged to organize these experts since the tendency to uphold individualistic forte that may create dissenting atmosphere.

Sawaguchi M. in his work suggested the next generation product scenario through the modification of TRIZ technique of *Patterns of Evolutions*. This is done during planning in *Information Phase*. *Patterns of Evolutions* explain the transition of subject (be it a product or process or system) within 8 laws of system development [5]. It is a TRIZ Trends as a system of laws that govern engineering system evolution with 8 patents formulated; 1. Technology follows a life cycle of birth, growth, maturity, and decline; 2. Increasing Ideality; 3. Uneven development of subsystems resulting in contradictions; 4. Increasing dynamism and controllability; 5. Increasing complexity, followed by simplicity through integration; 6. Matching and mismatching of parts; 7. Transition from macrosystems to microsystems using energy fields to achieve better performance or control, and; 8. Decreasing human involvement with increasing automation [6].

The second is the use of a modified I-TRIZ Software in the stage for reviewing the proposed concept in the *Development Phase*. I-TRIZ is a software developed by Ideation International Inc. (2002) that (among others) is to strategically evolving future generations of technological systems.

C. Yuan. L and L. J. Hsing suggested the integration of Design Chain Integrative Process Model with VE and TRIZ [7]. The model suggested using TRIZ in the *Information Phase* where information are collected and analyzed, and then the function analysis was developed. After completing function analysis, they started refining and assessing the contradiction hence eliminating harmful functions.

Further, after the *Presentation Phase*, they proposed Hybrid Value Study Model where some ideas or recommendations can directly be implemented with some changes will go through the design chain process for additional process of assuring product quality [7]. Hybrid Value Study model integrate VE/TRIZ with Design Chain Management (DCM), suggests further improvement on product design and reducing the risk of product failure in market.

The integration of VE-TRIZ-DCM suggested is a step-by- steps approach in improving product quality and values by incorporating Product Design and Development processes with aftermarket feedback as the end result. There is a potential to further improve the efficacy by implementing Hybrid Value Study (VE-TRIZ-DCM) up-stream, i.e. at the early of Product Design since product potential and limitation can be identified earlier.

Mao [8] proposed the use of TRIZ contradiction technique at VE *Creative Phase* in seven steps as shown in Figure 2; 1. Gathering of project knowledge; 2. Breakdown project into its sub-system; 3. Identify sub-system harmful function and rank according VE level of intolerance; 4. Identify and solve technical contradiction where during improving one parameter create a deteriorating parameter; 5. Identify and solve physical contradiction when dealing with single parameter that have contradiction of two directions; 6. Conduct Su-Field analysis for harmful function that cannot be explained through both technical nor physical contradiction, and; 7. Improvement through technical trend (or *Patents of Evolution*).

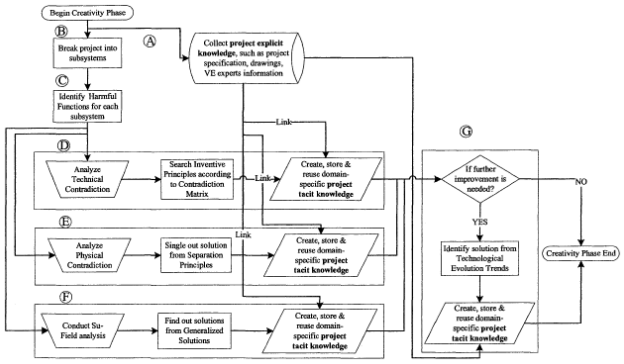


Figure 2 Creative Phase of TRIZ-enhanced Value Engineering [8]

The proposal of eliminating harmful function in sub-system environment will cover and overturn every function in the system that if miss-looked may leak into bigger problem in future. Another, the step in improving function through Patents of Evolutions is also interesting since it will guide improvements towards ideality. Altshuller has formulated ideality as the quotient of the sum of the system's useful effects divided by the sum of the system's harmful effects. Briefly, ideality is a function that can perform flawlessly with no cost and no harmful effect, as the systems evolve, they increase their degree of ideality. The sum of useful effects in the system are improving and the sum of harmful effects are reducing. Systems become more efficient and effective, although they rarely reach perfection [9].

3.0 PROPOSED VE-TRIZ INTEGRATION FRAMEWORK

The discussion of the proposed framework in this study is structured as follows: The first section will be discussing on the basic idea behind VE concepts and motivation of the research followed by an overview on the generic theory behind TRIZ ingenuity. The second section presents the description of the proposed framework and proceeded by discussion on the advantageous as well as foreseen limitations of the framework. Concluding remarks is made at the final section with some suggestions for improvement.

3.1 Research Motivation

Though VE had been alleged as a powerful tool to identify unnecessary cost associate with function of a subject, it has its own weakness during *Creative Phase*. Brainstorming is a novel technique used by VE but it depends on own experience, knowledge and creativity [3]. In other words, the idea thrown during brainstorming session are based on own experience and subject matter expert, there is a possibility of limitation in fresh idea [4] and recycle idea suggested. TRIZ, therefore, being investigated to support and catalyze idea generation.

3.2 New Framework

The proposed framework consists of four fundamental steps described as follows:

Step 1: Information. Involve with information gathering process related to components or products. These include project goal setting, analysing method, technical drawing, product specification, cost analysis and design/development/production history. This step is based on SAVE® VE's pre-study and information phases.

Step 2: Function Analysis. To identify and display each component function and sub-function using FAST diagram, identify the cost of each function and using Function-Cost-Worth analysis to identify value for improvement. This step is based on SAVE® VE's *Function Analysis Phase*.

Step 3: Idea Generation. To identify functions that; [i] are harmful, thus eliminate them through trimming process; [ii] need enhancement, improvement them using 39 Engineering Systems. On eliminating harmful function, instead of using Su-Field modelling which are capable of identifying different functions (useful, ineffective, harmful, incomplete), trimming method is used. It provides platform to remove components without affecting the functionality and easy for beginners to understand.

On function enhancement, simple problem of contradiction issues within the component's system are identify and resolve using contradiction matrix. For more eccentric or compounded problems, technical contradiction is used in a situation where improving one parameter will deteriorating other parameter, while physical contradiction is used when dealing with contradiction within a single parameter. Finally, contradiction matrix is used to generate ideas.

Step 4: Idea Evaluation, Development and Implementation. Evaluate the idea technically and commercially prior to management reporting and review. These include cost calculation before and after improvement, calculation of Future Value (FV) to determine the improvement feasibility and Life-cycle costing (total cost from product designing until product disposal, e.g. Design and fabrication cost, maintenance cost, assembly and disassembly costs). The overall architecture of the proposed integration framework is illustrated in Figure 3.

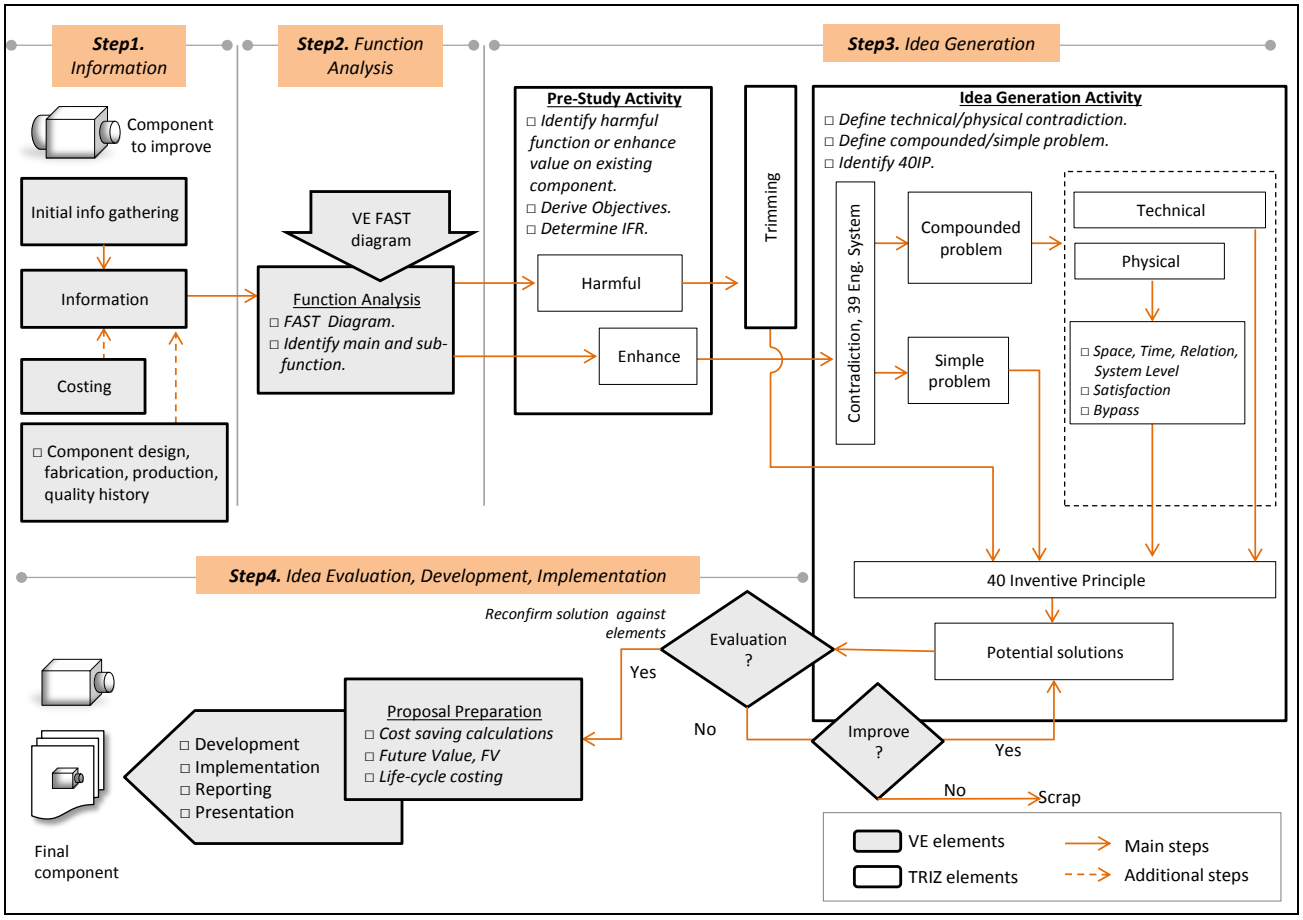


Figure 3 The Proposed VE-TRIZ Integration Framework.

4.0 DISCUSSION

4.1 Framework Strength.

In *FAST* diagram, components functions are generalize and segment into two distinctive functions; [i] harmful function- unwanted function that give 'harm' to the components and must be removed; [ii] function for enhancement- useful functions, insufficient functions or excessive functions that require improvements. By generalizing functions in such arrangement, helps to guide VE-TRIZ beginners into using specific TRIZ tools suggested.

The framework recommended most common and easy-to-use TRIZ tools to deal with contradiction. It suggests the use of 3-TRIZ tools: [i] Technical/Physical contradiction; [ii] Contradiction Matrix (39 Engineering System, 40 Inventive Principle); [iii] Trimming method. These tools can easily be trained, yet powerful in eliminating unwanted function and contradiction issues thus increasing component function ideality.

Potential solutions are check, measure, validate and verify both technically and commercially. On commercial ground, by performing feasibility study (life-cycle costing, FV), potential saving are check and compare against cost of improvement. Ideally, saving generates and accumulates through-out the balance of component life span are greater than the improvement cost.

4.2 Framework Weakness or Limitation.

Since the suggested framework is for beginner, the potential of other TRIZ tools will not be explored. This includes Su-field, 76 Standard Inventive Solutions and ARIZ (Algorithm for Inventive Problem Solving). Su-field and 76 Standard Inventive Solutions are the advance

TRIZ tools of solving technical contradiction by analysing substance relation and exploit knowledge from patent database. ARIZ is a comprehensive problem solving tools where other TRIZ tools are not capable of giving a breakthrough result, but with 85 steps to follow, it is tedious process especially for TRIZ beginners.

5.0 CONCLUSION

VE and TRIZ are both stand unique in their own ways. VE is suitable for system level problem while TRIZ is capable of finding solution on sub-system level. Even though very powerful in suggestion solutions, VE's brainstorming technique is falling behind due to its limitation. TRIZ is more structured with more than 20 tools, and all of these tools are potential to enhance VE activity. Most literatures recommended integrating TRIZ into *Value Job Plan* at Creative Phase due to obvious reasons: to boost problem solving activity, while some propose to integrate VE-TRIZ with other fields in search for product or system ideality. VE in one of the effective tools for product improvement and innovation; problem identification, analyzing and solution evaluation, and in order to support comprehensive product development, VE-TRIZ integration create an interesting alternatives [10].

In lieu to that, a proposed new integration framework between VE and TRIZ is proposed in this paper. Malaysian automotive industry is chosen to be the scope of study to visualize the effectiveness of the framework and several minor drawbacks are expected during the initial stage of implementation however, some idea of improvement is therefore proposed.

5.1 Opportunity for Improvement.

TRIZ's Function Analysis and VE's *FAST* diagram are almost familiar concepts of understanding subject performance through detail analyse of each components structure and function. TRIZ's Function Analysis represents subject-action-object interaction while VE's *FAST* diagram signify arrange of logic path and function in the cause-and-effect correlation. There is a possibility of merging these two concepts since both investigate component functions.

Acknowledgement

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