



## Integration of value engineering and theory of inventive problem solving (TRIZ) for increasing the value of industrial products: case study of air-conditioner

Ruephuwan Chantrasa\*, Charnchai Phontri and Veeraya Louangsinsiri

Department of Industrial Engineering, Faculty of Engineering, Burapha University, Thailand.

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### Abstract

Increasing the product value and decreasing the production cost are important factors for the success of manufacturing industries. This research aims to propose a systematic approach for product design and development by applying value engineering technique and Theory of Inventive Problem Solving (TRIZ). Air conditioning manufacturing industry was used as a case study in this research. The research methodology consisted of the selection of parts to be analyzed, data collection of parts to be designed, function analysis, idea creation and the application of TRIZ. Results from product analysis showed that the major part of air conditioning was the Electric Box Assembly which was composed of several minor parts. One of them was the Electronic box plate which was an important part and suitable as a sample part for the study of increasing the product value and decreasing the production cost. From the steps of idea creation and application of TRIZ, a systematic approach for designing the Electronic box plate was generated. This approach can reduce the amount of material used to manufacture this part more than 30% and also increase its value. This was because it can be designed to have a common function with a Partition plate, thus, the value of the Electronic box plate was increased.

**Keywords:** Value engineering, TRIZ, Product design, Cost reduction, Air-conditioner

### 1. Introduction

To survive in today's competitive environment, a manufacturer attempts to produce high quality and low cost products that satisfy customer needs. An air-conditioner is one of the highly competitive industry in which the manufacturers have forced to create innovative products, reduce product and manufacturing cost, bring profit to all stakeholders as a consequence. Value Engineering (VE) was developed by Lawrence D. Miles around 1947 as an improvement of cost reduction method [1-2]. To implement VE, Miles developed a five-step job plan to solve the system problem [3]. However, VE does not provide effective tools to design product that is complex and has inherent conflict in design. Moreover, the creative phase of VE relies on brainstorming process which requires a lot of time and effort of the VE team to generate innovative product ideas [4]. TRIZ (Theory of Inventive Problem Solving) is a powerful methodology for producing systematic innovation and improving the designer's thinking process. It is a concept generation process that can develop effective solution by using the condensed knowledge of thousands of past inventors [5]. TRIZ includes a set of tools and techniques which are (1) contradiction matrix and 40 inventive principles, (2) four separation principles, (3) Su-field analysis and 76 standard solutions, and eight pattern principles [4, 6-7]. The application of VE and TRIZ has been proposed by researchers in various manufacturing and

product setting. Jiayou and Yanxin (2009) proposed the methodology for selecting air-conditioning system for villa based on VE [8]. VE is also applied to reduce cost of household furniture product [9]. To solve the design problem, TRIZ is applied to design pizza package to prevent it from moisture and keep it hot during delivery [10]. TRIZ is also employed in combination with AHP to select the best automated assembly systems [11].

This research aims to employ the strength of VE as the systematic approach for analyzing product value and cost reduction. Air-conditioner was selected as a case study product in this research because it is composed of many complicated components which are interrelated among each other. To overcome the problem and conflict in design, TRIZ is also applied. Thus, an integration of VE and TRIZ is expected to be an effective method for improving an air-conditioner product. Finally, the systematic approach to improve the design of air-conditioner to be more valuable and lower cost by applying VE and TRIZ would be obtained.

### 2. Research methods

The methodology of this research consists of 6 steps as follows:

Step 1 Introduction Phase - The team members from various disciplines and the product model of an air-conditioner to be used as a case study product were selected.

Step 2 Information Phase – The details of parts and components of the selected product, as well as its assembly process were studied and their data were collected.

Step 3 Function Phase –The functions of selected components were analyzed by following these 2 steps:

Step 3.1 Identification and classification of the function –The function of each component was identified in the form of verb + noun. The functions were then classified as a basic function (essential function), and secondary function (supporting function) [3].

Step 3.2 Evaluation of importance – A pairwise comparison among all functions was conducted by rating its importance into 4 levels – 3 (major), 2 (medium), 1 (minor) and = (equally important) as proposed by Arthur Mudge [2]. The significant components, in which their functions had the highest important weight would be further used in the study.

Step 4 Creation phase – Concept classification tree technique was used to generate the design alternatives. The concept screening and scoring methods [12] were then employed to evaluate and select the best design alternative.

Step 5 TRIZ - If any contradiction occurred in the design alternative, TRIZ principles were applied. This research employed 2 principles of TRIZ as follows:

Step 5.1 Contradiction matrix and 40 inventive principles were employed to solve technical contradiction [6, 7].

Step 5.2 Four separation principles were employed to solve physical contradiction [7].

Step 6 Evaluation phase – The product design alternatives created in the research were compared and evaluated before actual implementation.

### 3. Results

#### 3.1 Selecting the case study product and components

This research selected the compressor unit of 9,000 BTU air-conditioner to be the case study product. The study focused only on the main components that would be used in the new product model. The cost distribution and the effect on both appearance and efficiency are criteria in selecting the main component to be studied. The component that has higher cost and less effect would be selected because it has high contribution in the production cost. In addition, the selected component should have minimal effect on the overall efficiency and appearance of the current product. In order to do so, the cost of each component was divided by the total cost of main components in compressor unit to calculate % cost distribution as shown in Table 1. The justification on its effect on the appearance and efficiency was performed by the VE project teams which included senior engineers from various departments in the company.

From Table 1, the electronic box assembly was selected because it had no effect on the appearance, partial effect on the efficiency, and had moderate percentage of cost distribution.

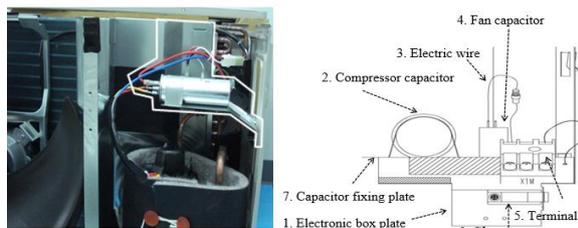
**Table 1** Cost distribution and effect of the main components in compressor unit

Main Component	% cost distribution	Appearance effect	Efficiency effect
Compressor	36.08%	×	✓
Hot coil	17.52%	×	✓
Refrigerant piping	7.48%	×	✓
Electronic box assembly	5.44%	×	□
Fan	1.02%	×	□
Structure frame	20.09%	✓	×
Fan motor	8.85%	×	✓
Label	0.14%	×	×
Box, manuals, and accessories	3.38%	×	×

Note : ✓ = full effect , × = no effect, □ = partial effect

#### 3.2 Information phase

The electronic box assembly consisted of 7 parts as shown in Figure 1.



**Figure 1** Parts of electronic box assembly

#### 3.3 Analysis phase

After all 7 parts of the electronic box assembly were analyzed for their functions, the analysis results can be shown in Table 2. Then the important weight of each pair of functions was evaluated as shown in Table 3. It can be seen that functions B and E had high important weights. However, these functions belonged to compressor capacitor and fan motor capacitor which could not be redesigned because they would affect the product efficiency. As the result, this study selected function A: support part to be improved. Thus, electronic box plate was the part to be redesigned to reduce its cost.

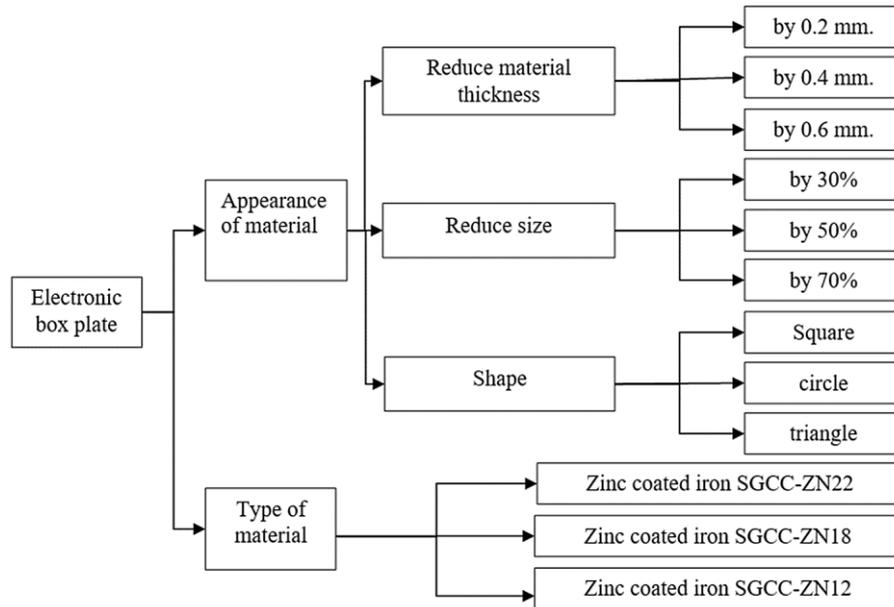


Figure 2 Concept classification tree

Table 2 Function analysis of electronic box assembly

Unit	Component name	Function		Function Classification	
		Verb	Noun	Basic	Secondary
1 part	electronic box plate	support hold	part part	✓	✓
1 part	Capacitor (Compressor)	discharge/store control	electric charge turning	✓ ✓	
1 unit	wire	connect	electrical circuit	✓	
1 part	capacitor (Fan motor)	discharge/store control	electric charge turning	✓ ✓	
1 part	terminal	connect hold	electrical system wire	✓	✓
1 part	clamp	hold protect	wire sliding	✓	✓
1 part	capacitor fixing plate	hold	part	✓	

Table 3 Pairwise evaluation of the function important weight

	B	C	D	E	F	Function	Weight
A	B-2	C-1	A-2	E-1	A=F	A: Support part	2
	B	B-1	B-2	B=E	B-2	B: Control rotation	7
		C	C=D	C-1	F-1	C: Connect electrical circuit	2
			D	E-1	F-1	D: Hold electrical wire	-
				E	E-2	E: Discharge/charge electric charge	4
					F	F: Hold part	2

3.4 creation phase

The electronic box pate currently used has 4 required specifications which are material thickness at 1.2 mm, dimension of 300 mm x 300 mm, square shape, and SGCC-ZN22 material. The electronic box plate design concepts were generated using concept classification tree as shown in Figure 2. Appearance of material and type of material were two main issues used for redesigning the electronic box plate. The appearance of material can be further separated to 3 attributes. Finally, at the end of the branch of the classification tree, alternative solutions according to the sub-

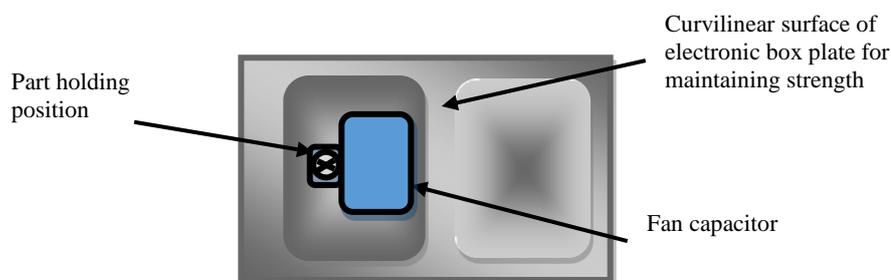
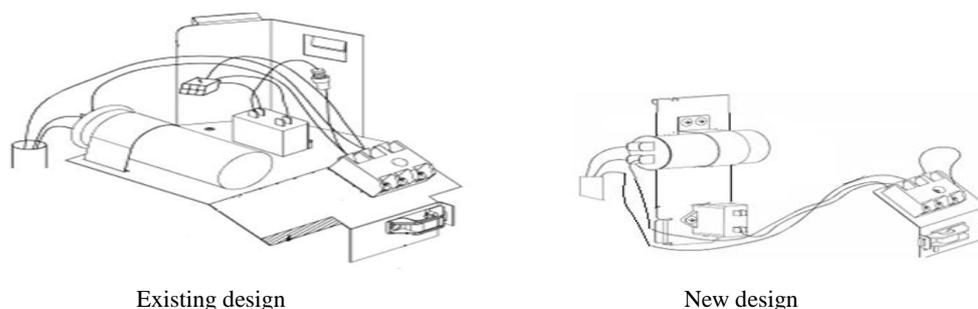
attributes were defined. As a result, there were totally 81 alternative design concepts of the electronic box plate. By applying concept screening and concept scoring [12] to evaluate the concepts, the most preferable concept was reducing material thickness by 0.6 mm, reducing size by 30%, square shape, and using SGCC-ZN22 as material.

3.5 TRIZ and evaluation phase

The new design of electronic box plate was to reduce the thickness and plate size, which can affect the strength and increase the chance of short circuit. TRIZ was applied to

**Table 4** Use of contradiction matrix [7]

Extract of the Contradiction Matrix		Parameter to deteriorate
		14. Strength
Parameter to improve	4. Length of non-moving object	15, 14, 28, 26
	8. Volume of non-moving object	9, 14, 17, 15
	12. Shape	30, 14, 10, 40
Inventive Principle	14. Principle of Spheroidality – curvature	
Principle		Instead of using rectilinear parts, surfaces, or forms, use curvilinear ones, move from flat surface to spherical ones, go from linear to rotary motion, use centrifugal forces

**Figure 3** Curvilinear surface of electronic box plate**Figure 4** New design of electronic box plate by TRIZ

solve these conflicts. In this case, parameter to be improved was the thickness which corresponded to parameters 4, 8, and 12 of 39 engineering parameters in contradiction matrix which is shown in Table 4. On the other hand, a parameter that was deteriorated was 14: Strength. From TRIZ matrix, the common solution to this design was 14; principle of spheroidality [7]. Hence, the surface of electronic box plate was redesigned from flat to curvilinear surface as shown in Figure 3. In order to avoid short circuit due to the reduction of the plate size, separation in space was applied by separating the electronic box plate into 2 pieces while maintaining the position of the electronic devices as standard. This new design reduced the space of electronic box plate by 30 % as shown in Figure 4 and material cost was reduced by 30%. The new design can increase the value of the electronic box plate by enhancing its function to hold the electronic devices and to be used as partition plate.

#### 4. Discussion

By applying VE and TRIZ in this research, the amount of product material could be reduced by 30%. However, this study had some limitations in selecting parts or components to be studied and improved, because it would affect the industrial standard of the product. In TRIZ, 39 parameters are so general that they might not reflect actual parameter of the study.

#### 5. Conclusion

This research attempted to fulfill the deficiency of VE by integrating problem-solving technique, TRIZ, to improve the design of electronic box plate which was in the compressor unit of the 9,000 BTU air-conditioner. The approach of integrating VE and TRIZ is expected to increase the efficiency and quality of the industrial product design.

#### 6. Acknowledgements

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