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Application of the Integrated QFD technique in the Design of an Innovative Machine for Cleaning the Drinking Water Tank

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Abstract

Due to the growing population and demand for clean water consumption, this research aimed to employ the Quality Function Deployment (QFD) to design and construct an innovative process for production of clean drinking water for small and medium enterprises. The QFD integrated various consumer-oriented product development techniques including Kansei engineering concept, the Theory of Analytic Hierarchy Process (AHP) for the selection of design parameters validated by users and the Theory of Inventive Problem Solving (TRIZ) to solve problems that originated from the new product. The innovative machine cleaning drinking water tank has a capacity of 360 units per day, a work methods reduction of 10.89%, and an employee reduction of 23.81%. The results of the test showed that the user satisfaction was very high.

Keywords Kansei Engineering, QFD, AHP, TRIZ, Technology Transfers

INTRODUCTION

Innovation is a key factor for today's sustainable business. Innovation is not just the application of knowledge to solve a problem, but can also used to bring about the creation of innovation. [1] Technological development is an important part of today's economic growth. Researchers and designers have the idea to develop advanced and sustainable design tools. [2] Companies continually create innovative designs by either developing at their own organizations or collaborating with larger companies. This leads to severe business competition which has an effect on small-sized enterprises that are the driving force of the economy, but inadequate technology.[3] QFD is a technique that transforms customer demand into innovative engineering design through process analysis.[4] However, there are limits to the technical features of the conflict in QFD. The use of TRIZ techniques integrated with the QFD technique will help solve product design problems to meet the needs of most customers.[5] On the other hand, applying Kansei engineering on product design development will meet the customer's emotional needs. [6]

Quality function deployment is a way of designing and developing products that focuses on converting customer needs into products and services. [7] It is a technique that can be used to design a product or industrial product that has already been reused as a new system. [8] Additionally, QFD technique helps to determine the appropriate design factors when integrated with qualitative TRIZ and ANP techniques. There are various factors for designing a polyethylene tube compression device to stop gas flow without breaking the pipeline. [9] QFD is also a tool for sustainable product development. Because this technique helps to make informed decisions about the environmental requirements of the product: ECQFD represents a new concept that will enable organizations to increase their competitive edge. [10] Knowledge management using QFD technique can meet customer requirements by either weighting design factors for design or development of new products or continuously improving quality of products to meet customer needs.

Kansei engineering was founded by Dr.Mitsuo Nagamachi, a Japanese researcher, in the 1970s. It is a technique that transforms customer's feeling for a product into design and development criteria. [11] A study for development of a mechanical display booths prototype using Kansei engineering technique showed that the attributes consumers can convert into adjectives are contemporary, simple, professional, not boring and stylish. [12] Additionally, Kansei engineering is a part of product design that is based on information gain from exploring the products already used on the website and introducing new products to meet the needs of customers. [13] In this article, Kansei engineering is used to assess customer needs in the early stages so that the design process meets the needs of most customers.

TRIZ is the theory of inventive problem solving that originated in Russia. [14] In 1956, an engineer named Genrikh Altshuller identified a solution to a conflict on the basis of numerous technical innovations. In the year 1969, Altshuller made presentations about "The Innovation Algorithm." [15] The technique was later known as ARIZ (Algorithm of Inventive Problem Solving) which involves 40 basic techniques and principles. [16] The TRIZ technique has been used in research to solve technical conflicts in product or service design. [17] In order to make the design effective in this article, we have applied the TRIZ techniques as part of the quality function deployment.

AHP is one of the widely accepted techniques used in decision making. The analytic hierarchy process was invented by Thomas Saaty in 1970. [18] AHP is a technique used to divide a problem into parts. In the form of a hierarchical chart, the weight of each component is then calculated. This leads to the priority value of each choice and is used to make decisions. [19] Lee identify the need of management for designing a service system using the Kano and AHP models. [20] Hosna

Pakizahkar conducted a study intended to prioritize the needs of bank clients in Iran by integrating the Kano model, AHP technique, and QFD. It was found that customer needs and communication are most important. [21] In this article, AHP is used to prioritize customer needs in the design of a machine cleaning drinking water tank.

Technology transfer is a very important process in innovation management. The success of technology transfer lies in the regulation of the regulatory environment such as the government's policy on foreign investors' and investment in technology transfer to their own industrial plants. Understand of the international standard is required for a successful technology transfer. [22] Mikus Dubickis and Elina Gaile-Sarkane investigated the relationship between innovation and technology transfer and found the three different modes, as shown in Figure 1.

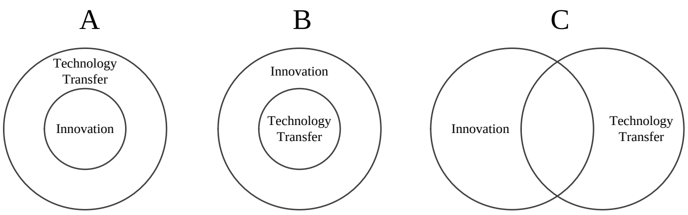

Figure 1. Relationships between innovation and technology transfer.

In Figure 1a, technology transfer involves innovation. In Figure 1b, innovation development involves technology transfer. In Figure 1c, innovation and the transfer of technology overlap. [23] Ayse Gunsel reported that the efficiency of technology transfer is significate effected by the knowledge management protocol of each enterprise. The results revealed that explicit knowledge has a significant effect on technology transfer efficiency while tacit knowledge has no significant effect. Therefore, it is necessary for the enterprise to record the latent knowledge created by an accountable person. This may be done by a computer program, engineering drawing and writing charts, etc. [24] So far very little work has been done on integration of these four product design techniques for production of protype.

This article introduces the integration of design techniques such as Kansei engineering, QFD, AHP, and TRIZ to generate a prototype used in the factory to produce drinking water for small and medium enterprises. It is designed to meet the needs of the most demanding users and increase the efficiency of the plant.

METHODOLOGY

The researcher used the quality function deployment technique as a fundamental consideration for the product design process. As shown in Figure 2, Kansei engineering, AHP and TRIZ were implemented along the way and finishes with the technology transfer step to small and medium enterprises.

Kansei engineering technique was used in the first stage of the process to identify emotional characteristics, which ultimately lead to the users satisfaction. Additionally, the demand factors are grouped and the demand-weighting was analyzed using AHP. User requirements found from this stage are converted into engineering features. The machine for cleaning drinking water tank is then designed and evaluated by experts in the field of engineering and operators. Following the first stage, the TRIZ technique was applied to resolve problems regarding technical requirements from the first stage. The design characteristics conversion is a part characteristics and a key process in the operation. The technology will eventually be transferred by converting the knowledge into a practical approach in the third stage. In this study, the prototype was tested by small and medium enterprises located in Sakon Nakhon, Nakhon Phanom, Kalasin, Mukdahan, and Bungkan provinces in Thailand.

RESULTS

Data collection was performed by interviewing a total of 10 entrepreneurs and workers in the production of drinking water. To analyze the results as shown in Figure 3 below, the importance rating score (with a score of 1-9 ranked by importance) and Expert Choice program were used.

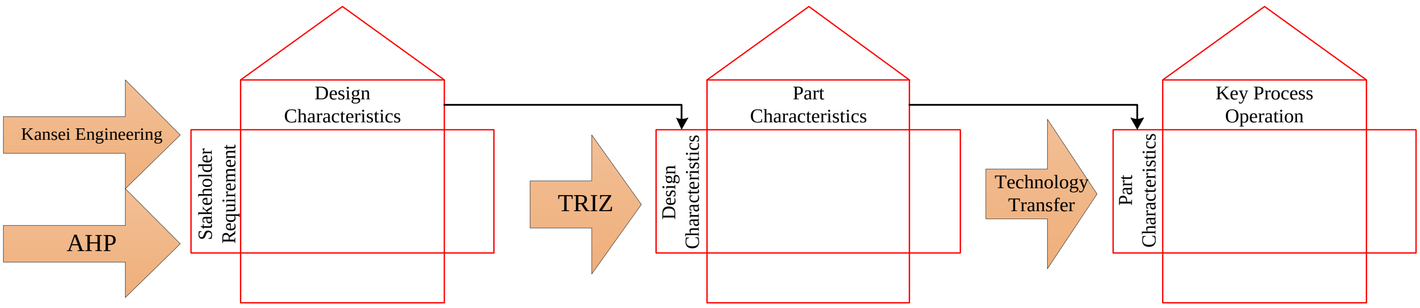

Figure 2. Integrated quality function deployment distribution technique.

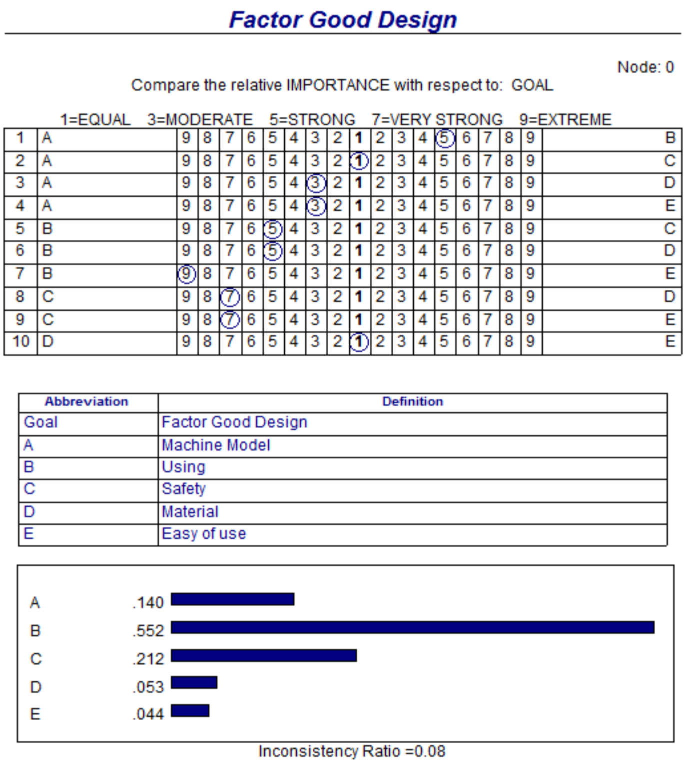

Figure 3. The weight of the main factors in the design of the machine cleaning drinking water tank from the Expert Choice program.

Figure 3 shows the importance of each key factor from the assessment of the drinking water plant and the staff working in the production process. The ratings are from 1 to 9, with a pair factor comparison and analysis from Expert Choice program.

Figure 4 shows the results of user requirements and the first three priorities that were used to model the factors affecting the design of the machine cleaning drinking water tank.

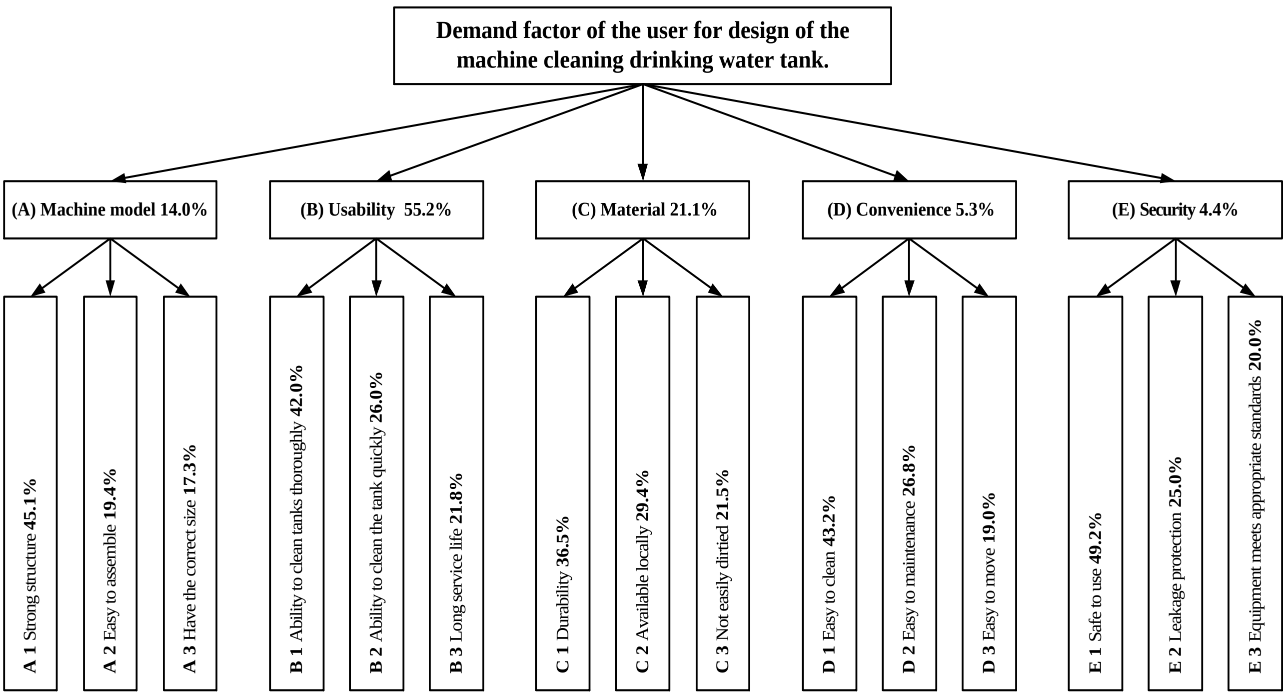

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Figure 4. User requirements model that results in the design of a machine cleaning drinking water tank.

The AHP model combined with the QFD techniques was implemented in the design of the machine cleaning drinking water tank. The customer need factors derived from the AHP model were used in the product planning matrix of a quality home. The results from the conversion of the customer need factor into the engineering features are shown in Figure 5.

Movement Of Target Value
↑ Increased target value will be good.
↓ The target value drops are good.
O Set up a good goal already.

Part Characteristics	IMP	Cleaning equipment is of quality and standard	Component durability	Production capacity	Size of the motor must be appropriate	Material does not rust	Manual is easy to read	Close - open and bring the tank into - out easy	Number of joints	Control devices must have quality	Have a wheel at the base to move it	Power cutting equipment must have quality	Signal warning light	
		↑	↑	↑	↑	↑	O	↑	↓	↑	O	↑	O	
Clean the tank well	17.86	9		3	1			1						
Long service life	9.84		9			3				1				
Price of machine	8.15	3		3		1						3		
Strong	7.84		9			3								
Wash the tank quickly	7.58	3		9	1			9						
Corrosion resistant	6.75		1			9								
Removable and easy assembly	6.38					1	3							
Manuals are available	6.27				1		3					3		
It is fast in operation	6.19			9				9						
Standard control unit	5.02									9		1		
It is easy to move	4.00										9			
Short-circuit protection device	3.90											3		
Use durable equipment	3.86		3			3				3				
Operational time signal	3.73												9	
The material does not wear out of work	2.61		1			3								**Total**
(Raw score)		207.93	180.06	201.96	31.71	124.21	37.95	141.79	0	66.60	36.00	59.98	33.57	**1121.76**
(% Relative)		18.54	16.05	18.00	2.83	11.07	3.38	12.64	0	5.94	3.21	5.35	2.99	**100**
(Rank)		1	3	2	11	5	8	4	12	6	9	7	10	
Target of sub-components		Used brush to clean the tank standard	No damage from use within 2 years	Can be cleaned outside - inside simultaneously	Use motor size suitable	Use stainless steel structural machine	Use pictures - easy to read in manual	Use the easy-to-open system	Number of screws to a minimum	Control unit is not damaged within 3 years	Use the wheel to move	Power cut off immediately	Use the switch with a warning light while running	

Figure 5. Matrix transformation of QFD into Part Characteristics.

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Table 1 shows the results obtained from the conversion of QFD into part characteristics. Part characteristics are prioritized by weight.

Table 1: Sorting weight of importance part characteristics subassemblies

Rank	Part Characteristics	Absolute Part Char. Importance	% Relative Part Char. Importance
1	Cleaning equipment has high quality and meets standards	207.93	18.54
2	Production capacity	201.96	18.00
3	Component durability	180.06	16.05
4	Ease in closing and opening and portability	141.79	12.64
5	Material does not rust	124.21	11.07
6	Control devices have high quality	66.60	5.94
7	Power cutting equipment has high quality	59.98	5.35
8	Manual is easy to read	37.95	3.38
9	Has wheels at the base to move it	36.00	3.21
10	Has signal warning light	33.57	2.99
11	Size of the motor is appropriate	31.71	2.83

The result of the part characteristics design of the first machine cleaning drinking water tank was shown in Figure 6. The researcher collaborated with entrepreneurs, production workers, and mechanical design experts. The advantages and disadvantages of a basic design machine were considered.

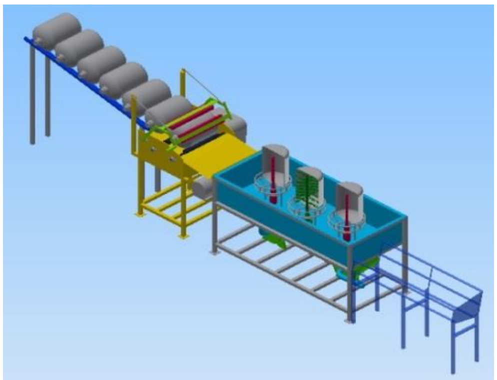

Figure 6. The first prototype of a machine cleaning drinking water tank.

When considering the prototype of a machine cleaning drinking water tank, it was found that the technical specifications were conflicting. The capacity demand in times of need is not met by the size of the prototype, which is too small. In order to reduce the space required for placing and moving the machine, the researcher applied the TRIZ technique to solve the problem. Using the matrix conflicts of TRIZ technique, the solution is shown in Table 2.

Table 2: Solutions to technical issues

Features to Improve	Decrease Features	Solutions			
12. Shape	32. Ease of Manufacture	1	32	17	28
	39. Productivity	17	26	34	10

TRIZ was used to solve the problem associated with the prototype drinking water tank. It is divided into 2 work stations: machine cleaning drinking water tank washed with outside and inside liquid and machine cleaning outdoor and inner water pump. The model of the machine cleaning drinking water tanks are shown in Figure 7.

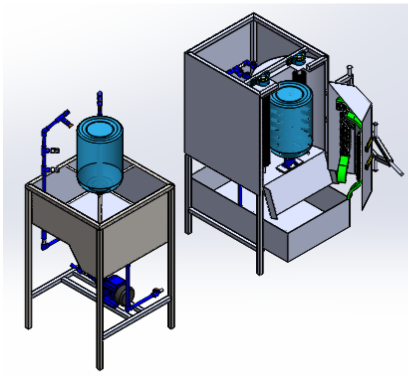

Figure 7. Machine cleaning drinking water tanks model.

The result is an improved design. The researcher has developed prototypes for the machine cleaning drinking water tank. The prototypes have the characteristics shown in Figure 8.

a. Station 1 b. Station 2

Figure 8. Innovation machine cleaning drinking water tanks.

The machines' performance was tested with 5 small and medium enterprises through technology transfer to their operators. The user manuals of the machine cleaning drinking water tanks include safety requirements, structure and composition of the machine, work procedures, troubleshooting and maintenance.

Figure 9. Technology transfer to small and medium enterprises.

The results of technology transfer and performance testing of workers found to reduce (1) the operating procedures, (2) the time spent washing the bucket, and (3) the number of employees involved. The users were very satisfied.

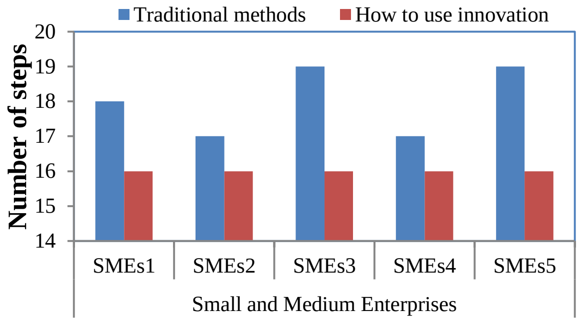

Figure 10. Comparison of working methods of SMEs by technology transfer.

Figure 10 shows technology transfer information to 5 SMEs. It was found that the process of drinking water production average was reduced by 2 units, increasing the efficiency by 10.89%.

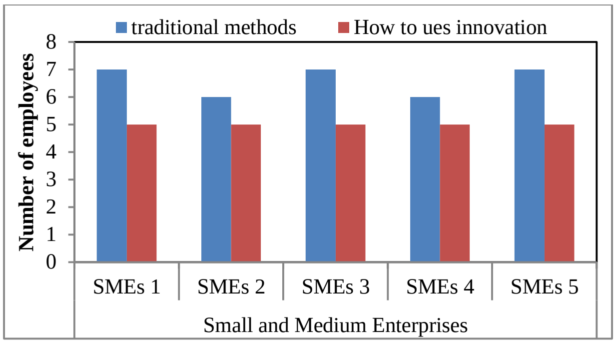

Figure 11. Comparison number of employee of SMEs by technology transfer.

Figure 11 shows technology transfer information to 5 SMEs. It was found that the number of employee production average was decreased by 2 people increasing the efficiency by 23.81%

CONCLUSIONS

Through the integration of various engineering techniques for machine design, an innovative prototype machine cleaning drinking water tank was produced that has a capacity of 360 units per day, can reduce the work process by 2 units on average with 10.89% efficiency, and can reduce the number of employees by 2 people on average with 23.81% improvement in efficiency. The results of the satisfaction assessment showed that the users were satisfied at a high level.

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