Improvement Of Efficiency In Product Designing To Reach World Class Competency By Using Of QFD & TRIZ

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Abstract

Nowadays, considering the wide commercial competition among companies, customization of products and services is regarded as a crucial problem to reach world class. That is to say companies must recognize customers' demands and implement them in their products technical requirements. Furthermore; to apply the products technical requirements, companies must resolve the technical requirements conflicts as soon as possible. The current study provides researchers an instrument for designing customized transformers in Transfo Company. In this regard, first, fuzzy QFD tool is implemented. In the House Of Quality matrix process, fuzzy Analytic Hierarchical Process (FAHP) is implemented for weighting customers' requirements and advanced decision-making software is used for calculating adaption coefficients, respectively. But there are some conflicts among technical requirements to satisfy customer requirements. So, TRIZ instrument is used for resolving the conflicts among technical requirements in short time based on the customer requirements priorities. Regarding its purpose and data collection method, this research is an operational case study. This research statistical population consists of Transfo company's experts that are familiar with designing of customized transformers. Due to expert's limited number, no sample selection method was used. Questionnaires' validity was confirmed and their permanence was proved through calculating adaption coefficient.

Key words: QFD, House Of Quality matrix, Fuzzy Theory, FAHP, TRIZ.

۱- Introduction

Implementing an active prospective approach is much more effective in preventing product collapse during designation process's initial phases than taking a passive and reactive action in difficult situations. So, an instrument must be used for improving products innovation and withstanding in competitive environments (Regazzoni & Russo, 2011). By considering the fact that customers purchase products to fulfill their needs, companies must detect customers' demands and translate them into a clear language for establishing technical requirements. To respect customers' needs and focus on products qualitative requirements, companies must rank these requirements. Furthermore, they must detect and rank product designing characteristics. The technical requirements ranking is based on the qualitative requirements ranking.

But the main question is if the above-mentioned steps are sufficient? Can companies design their products by ranking technical requirements based on customers' requirements in a real world? Also if the designers face a problem during product designation, Will they have enough time to resolve it? Won't they need specific criterions or approaches for solving these problems? So, product designation instruments must detect and rank technical requirements of product designation according to customers' requirements and ensure their applicability in the real world through resolving their conflicts. By using try and error method for resolving the conflicts, experts cannot keep their companies in the competitive environment; due to time restriction, by consideration of competitive intensity and necessity of agility in production management. So, it is necessary to use established criterions for designing products and resolving designation conflicts. Using these criterions, experts can come up with innovative methods for agile production, follow customers' needs in product designation, minimize problem-solving period and keep up with competitors.

Quality function deployment instrument (QFD) can rank product designation's technical requirements based on customers' qualitative requirements. For obtaining more precise results, more precise scales must be used. Triangular fuzzy numbers can help researchers in this regard.

To implement QFD output- which is the product's technical requirements ranking, experts must first resolve the probable conflicts between these rankings and their environments. This operation must be performed in the shortest time to enable companies keep up with the competitive market. Here by using systematized innovation technique, experts can fulfill both objectives.

This research case study consists of Transfo company's specific transformers. Transformer product was selected due to the fact that in electronic industries, designation process is easier and more applicable. So, it is reasonable to seek a product that the tools can be more applicative.

This study mainly aims at increasing product designation efficiency (of producing specific transformers) in Transfo Company.

In this regard, the research main objective is broken down into the following subordinate objectives: detecting the customers' customization requirements, determining the technical requirements priorities based on customization requirements in product designation, resolving probable conflicts among designation requirements or product designation system parts without compromising on these conflicts.

2- Review of literature

1-2- Quality Function Deployment

Quality Function Deployment (QFD) is defined as the way that designers realize the quality their customers expect to appear through dynamic process (Shahin & Nikneshan, 2008). QFD is also realized as "House Of Quality matrix". This is due to the fact that the matrixes creating alignment in QFD, form a house-like diagram (Shahin & Nikneshan, 2008). QFD is a four stage strategy conducted using a series of production team activities' matrixes. The necessary standard documents are obtained during production and development process. The four strategy is described as following: 1- product planning; 2- product design; 3- process planning; 4- process control planning (Shahin & Nikneshan, 2008). Each stage matrix consists of vertical columns of "whats" and horizontal row of " hows". "whats" are customers' requirements. "Hows" are the way of satisfying customers' requirements. At each stage, "hows" are transferred to the next stage as "whats". As a result, house of quality matrix might be designed in different forms. The general objective of designing a QFD model is to detect customers' requirements, ranking of customers' requirements priorities, competitively assessing customers' market, developing of production technical characteristics, designing of correlation matrix, determining of key objectives, technically assessing of the problems, designing of relationship matrix and competitively assessing of technical control characteristics of the product characteristics. (Shahin & Nikneshan, 2008)

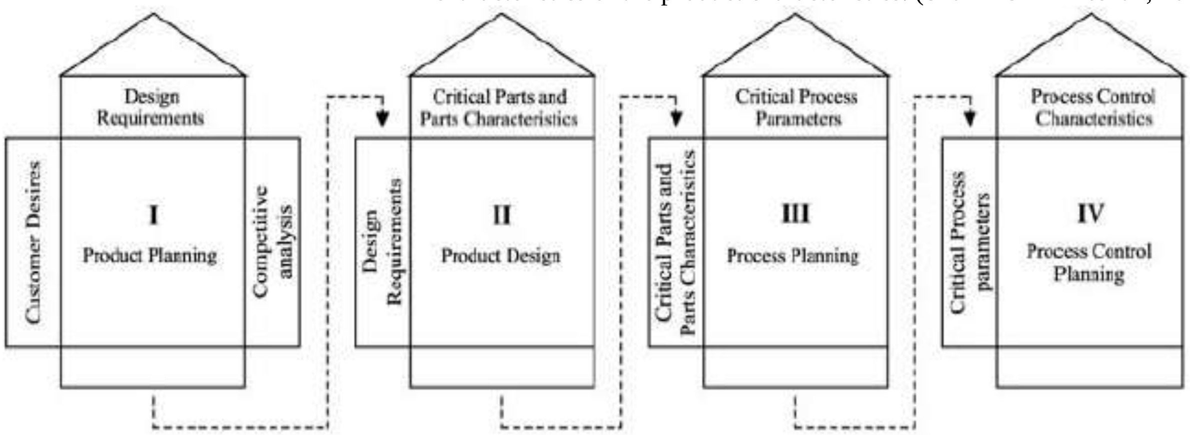


figure (1): house of quality matrix four-stage process (Kohen, 1995)

In the house of quality matrix, customers' requirements, in other word, "whats" inputs are demonstrated on the left column. On the right, customers' competitive assessments of quality alternatives are inserted. The upper limits reveal the technical requirements needed for fulfilling customers' quality requirements and the bilateral relationships between these technical requirements on the roof. Matrix middle cells demonstrate the bilateral relationships and degrees of relationships between customers' quality requirements and technical requirements. Matrix lower cells show the outputs- technical requirements priorities in product designation (Xiafei et al, 2012).

Leveraging the introduction and execution of this four stage QFD, it can be quickly and efficiently certified whether design changes or innovative product concepts meet customer specifications, target quality level and target cost (Yeh et al, 2011).

2-2- TRIZ

Implementing this systematized technology process; Genrich Altshuller renovated the innovation and exploration technology. Nowadays, systematized innovation is called TRIZ. TRIZ is a Russian acronym pronounced. Its English translation is "Theory of Inventory Problem-Solving"(TIPS) (Terninko, 2001).

Nowadays, product designation decision-making is crucial for keeping up with the competitive market environment. But, neglecting customers' requirements in technical requirements threatens organization existence.

So, an appropriate model must be implemented for relating between the two mentioned requirements and translating customer demands into technical requirements. Sometimes, designation requirements do not correspond or some repeated approaches are implemented in product designation processes without considering system environment changes. So, an appropriate model must be designed for resolving these problems and conflicts.

Realizing the fact that conflicts might be regularly resolved using innovative solutions is one of the three presuppositions of TRIZ. The three mentioned presuppositions are as following: 1) objective of achieving an ideal design; 2) conflicts help problem-solving; 3) an innovative process is systematically established (Terninko, 2001).

The main fault of the traditional innovation improvement processes is that they are not enough effective in complicated situations. Try and error method might be implemented for all processes but it must be considered that much try is needed for solving new complicated problems. Several generations of experts must attempt to solve a problem. Altshuller (TRIZ founder) was bound to facilitate complicated problems' solving process and share the facilitation method with other experts. His attempts to improve innovation process led to TRIZ designation. Altshuller main questions regarding innovation knowledge development were:

1- How to shorten innovation achievement route?

2- How to design a process for improving critical thinking? (Terninko, 2001)

Altshuller realized that many similar solutions have been repeatedly used for long distant time periods. So; providing innovators with a basic solution, it can enable them to implement the solutions in close time periods. As innovative processes' effectiveness increase, development gaps decrease and borders among technologies disappear. The traditional method of innovation improvement is to jump from a specific problem to a specific solution. On the other hand, the route to a specific solution is unrepeatable and needs endless haphazard attempts. This fact reveals the traditional method's incapability of solving problems since it spends too much time and cost for achieving ideal solutions. So, there is a need for an instrument without the above-mentioned limitations. Rejecting try and error method in innovative processes, TRIZ attempt to decrease innovation time through changing specific problems to general problem (Terninko, 2001). In other words the high- level steps of TRIZ methodology are: 1) define specific problems, 2) convert in to standard problems, 3) generate standard solutions, and 4) convert into specific solutions(Tzong et al, 2012).

TRIZ provides a set of basic knowledge to solve the contradictions and also can generate new knowledge during the process of removing the contradictions. The contradictions in TRIZ mean functions that can lead to two results namely, useful and harmful. It can also mean that the introduction of the useful function or the elimination of the harmful function will lead to one or multiple subsystems deteriorations. As a result, the technical contradiction is usually the contradiction between two subsystems in a main system. TRIZ is composed engineering parameters and 40 inventive principles deploy in research (Tzong et al, 2012).

3-2- QFD-TRIZ relationship

As explained above, the final output of the house of quality matrix in QFD process is technical requirements' ranking. that is not final of the work.

As QFD reveals the "whats" of required operations, TRIZ instrument determines "hows" of the required operations.

Taking an innovative, active and prospective approach is much more effective than showing passive reactions in preventing product collapse during its initial designation stages (Regazzoni & Russo, 2011). So, an instrument is necessary for resolving oppositions and conflicts rather than compromising on them. The implemented instrument must widely focus on products innovation. Due to the fact that customers purchase products to fulfill their needs, companies must translate customers' needs into TRIZ language in order to achieve a unique status in the market (Pelt & Hey, 2011).

The relationship between QFD and TRIZ is demonstrated in the following figure.

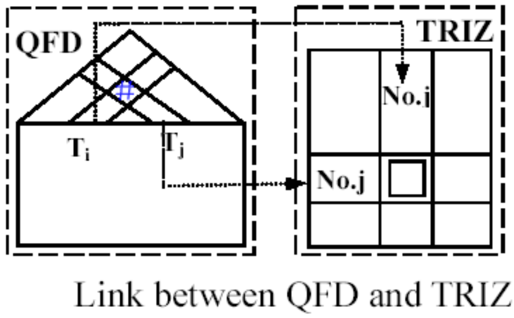


figure (2): the relationship between QFD and TRIZ

House of quality matrix's roof reveals the bilateral relationships between technical requirements. Simultaneous fulfillment of all technical requirements is impossible. Considering the technical requirements' final ranking obtained from the house of quality matrix, one technical parameter's improvement leads to other parameter's weakness. This situation is called opposition or conflict. To resolve these conflicts, TRIZ instruments is implemented to translate technical requirements into 39 designation parameters. In the matrix called contradiction matrix, ameliorating and deteriorating parameters are arranged in rows and columns, respectively. To resolve the conflicts, 40 main parameters have been used extracted for this purpose (Lu et al 2006).

In their article called "case study of implementing fuzzy QFD in TRIZ for improving services quality", Su & Lin concluded that the applicative TRIZ method must be implemented at the initial problem formulation stages. Otherwise, abstract and ambiguous discourse of problem-solvers will hinder agreement on the results. Of course, effects of these problem-solving conditions have been rarely discussed by TRIZ users. The main problem is that the TRIZ-based innovative solutions are influenced by inappropriate and ambiguous characteristics of engineering parameters. In this regard, research application of TRIZ method has been focused on fuzzy QFD implementation for investigating the correlation between customers' ambiguous requirements and service quality characteristics and determining the critical requirements related to customers satisfaction. As a result, the conforming parameters of TRIZ engineering can be extracted more precisely and explicatively (Ton et al 2008).

Yeh et al proposed a four- phase QFD involving TRIZ thinking strategy to enhance breakthrough capabilities for preventative and proactive design in product R&D process. Using TRIZ to propose innovative methods (integration of QFD 1~4, DFM (design for manufacture) and TRIZ) to resolve problems, the managers may anticipate the end result of the product development process will be both innovative and successful(Yeh et al, 2011).

In the following paragraphs, some of the other studies conducted on the systematized innovation technique have been mentioned:

Tzong et al, derived detailed literature corresponding to marketing model to solve operational problems and core operational problems of the aquatic products with traceability systems in Taiwan along with the detailed literature of TRIZ theory. Later they used TRIZ theory to propose strategies to solve defined problems and discussed their applications (Tzong et al,2012)

Wang & Chen, tried to abroad implementation of 6sigma approach in industry service, and combined TRIZ methodology with this approach for increasing application of traditional 6sigma techniques. Results indicated that combining of this two tools are useful in improving of banking services (Wang & Chen , 2010). Kim & Yoon implemented TRIZ and QFD instruments for resolving the conflicts between production and consumption requirements in 500 automobile factories in the world. Their findings revealed that implementing 40 TRIZ principals can fruitfully resolve production and consumption requirements conflicts (Kim & Yoon, 2012). In the other study, Zheng implemented a combination of QFD and TRIZ methods. In this new method based on QFD house of quality matrix, TRIZ theory and data envelopment analysis method have been used for resolving little-used product problems and selecting TRIZ technique-based solutions, respectively (Zheng & Zhang , 2010).

Having investigated the TRIZ knowledge applicability in pure production projects, Fresner revealed TRIZ instruments' main applications in using mere general knowledge for innovative problem-solving. This is due to the fact that TRIZ translates the solutions based on complex and specialized chemistry knowledge into general knowledge-based solutions and proposes 40 principles for resolving conflicts (Fresner & Jantschgi , 2010). Having investigated the TRIZ pedagogical courses effects on engineering students, Belski concluded that the students' perception of their problem-solving abilities had been significantly improved. Using other techniques, they could not have thought of achieving such an innovative problem-solving speed (Belski,L, 2011). Farias & Kane implemented a simulated version of TRIZ instrument in logistic activities. In other words, the translated 40 principles used in TRIZ contradiction matrix into three main logistically important variable groups-time, information and resources- and used them for resolving logistic activities conflicts (Farias

& Akabaneh , 2011). Filippi et al implemented TRIZ instrument for finding appropriate solutions for accelerating projects capital return rate in small and middle companies (Filippi & Motyl , 2011). Farshad et al applied TRIZ instrument in value engineering. Their findings revealed that implementing TRIZ instrument for investigating products functions helps researchers detect both useful and harmful functions of products while value engineering technique only detects useful product functions (Farshad et al, 2009).

Vinodh et al proposed a model that integrated environmentally conscious quality function deployment (ECQFD), TRIZ and analytical hierarchy process (AHP) for innovative and sustainable product development of automotive components. The voice of the customer (VOC) was captured and translated to engineering characteristics using ECQFD. Design options were identified using ECQFD and correlated with TRIZ to identify innovative design alternative. Selection of the best design alternatives under many criteria is a typical multi criteria decision making problems, the authors used AHP to identify the best design in terms of innovation and sustainability (Vinodh et al, 2013).

Muruganantham et al, have implied that lean manufacturing is an emerging philosophy for reducing the wastages and TRIZ is an inventive problem solving tool in times of economic recession. They proposed a synergistic approach of lean with TRIZ. As there was an inevitability of reducing the cost of the product, in their paper, lean had been utilized to identify the wastages and TRIZ was used to find optimal way to reduce wastages by solving contradictions. This synergistic concept was illustrated with a case study done in a fabrication sector and had visualized improved results (Muruganantham et al,2013).

Shahin et al, noted that contradiction in the process of product design during translating customer's kansei[1] (feeling and demands) makes this process more complicated, so to resolve this contradiction, TRIZ was used. For this purpose, a comparison had been made among TRIZ and kansei engineering parameters in order to take advantage matrix and respectively, a new contradiction matrix had been proposed for product design. The developed matrix was eight by eight in which eight pairs of kansei words as parameters, and 40 inventive principles were placed in the matrix cells (Shahin et al, 2013).

To fulfill the main research objective, it must be focused on subordinate objectives such as detecting customers customization requirements, prioritizing product designation technical requirements based on customization requirements, resolving the probable conflicts among designation requirements or designation system components rather than compromising on these conflicts. So, research questions are mentioned as following:

3- Research questions

1) How customer needs are prioritized at product designation stage? In other words, for becoming survive in competitive market, at the first time company managers must be sure that they have identified and classified customer requirements suitably.

2) How product designation requirements are prioritized based on customer requirements? This means that at the next step, for satisfying customers needs, their qualitative requirements must be considered on product designing.

3) How product designation system conflicts are relatively recognized using TRIZ instrument? In other words, in practice, doing all of the technical requirements that are identified on the basis of customer requirements at the same time because of some conflicts that are between them is impossible. So the need to find conflicts between these technical requirements by using a scope and context to prevent waste of time as soon as possible is necessary.

4) How product designation system conflicts are resolved using TRIZ instrument? In other words, after identifying conflicts between technical requirements, for remaining in competitive market, there is a need to solve these conflicts by principles that provide the best solving. These principles will be introduced by TRIZ

4- Methodology

[1] - Nagamachi defined kansei as a Japanese word that indicates customer's feeling about color, size, design, mechanical aspects, price, etc. of a product (Nagamachi, 1995).

This research is considered as an applicative research. It is going to apply the principles obtained from basic science branches such as physics in management decision-making processes and increase products efficiency. That is to say that there is a witness of technological transfer Due to the current relationship between basic sciences and management sciences, and basic sciences contributions are applied in management sciences. Due to investigate of specific transformer as system and the objective of increasing the designation efficiency, current research is a case study. Also Due to the limited number of experts and specialists that are familiar with specific transformer designation, no sampling method is implemented in this study.

4-1- Data gathering method

Four questionnaires have been used in this research:

Due to lack of specialized knowledge on transformers, the researcher has used innovation situation questionnaire (ISQ) as an open answer questionnaire as first research questionnaire. This questionnaire help to identify the system, it's components and environment.

Experts believe that if problem definition is done correctly, the half of the problem has solved successfully. So, for implementation of TRIZ, the problem must be first defined in a precise and accurate manner. The problem must be conspicuously investigated and its components must be recognized. Recognizing the systems' surrounding is prerequisite of the innovative solution. Having investigated the problem from different perspectives, experts must document all problem data. Innovation situation questionnaire helps researchers in fulfilling their objectives (Terninko, 2001).

It is possible that the problem is not accurately recognized and operationally defined and it's data are not available for experts. To solve this problem, TRIZ has gathered all required data systematically and made them available to experts. Then this structured data is used at the next stage of TRIZ for reformulating the problem and breaking it down to it's components.

Considering the fact that in product designation process, problem definition requires the comprehensive definition of the designed product- including physical, applicative, fiscal, qualitative and operational characteristics; the ISQ can work effectively due to it's essence (Tahmasebipour & Shahbazi, 2012).

Furthermore, ISQ enables users come up with a new formulation structures. Most detailed problems can be operationally defined in a simple manner. Considering the problem environment, backgrounds, resources, pollutions, favorable and unfavorable consequences; this questionnaire sections provide us with a comprehensive image of the problem (Shahbazi & Hejazi, 2012).

The second questionnaire is called analytic hierarchy process (AHP). This questionnaire aims at weighing the specific transformers recognized in first questionnaire. The extracted weighs are customers' quality requirement weighs detected by organization experts. So, specific transformers are compared in couples based on customers' qualitative variables using analytic hierarchy process.

The third Questionnaire aims at investigating bilateral relationships between technical parameters in specific transformers designation. The bilateral relationships between each of two parameters are investigated using the fuzzy scales. Furthermore, ISQ is implemented for detecting the direction of technical requirements relationships. This is due to the fact that recognizing technical parameters and their limitations and relationships direction are among the factors recognizable using ISQ. Considering the explained questionnaire components, this research study system is transformer. Limitations of this kind of transformer are those recognized as customers quality requirements. This kind of transformer (normal transformer) doesn't able to satisfy all customers' requirements. So, the specific transformers similar to the former transformer are recognized. Each specific transformer is designed to make up for some limitations of the former ones.

Forth Questionnaire aims at assessing each specific transformer effect on designation parameters changes, compared to that of normal transformer.

Specific transformers have been weighed by experts based on customers' quality requirements using second questionnaire. To insert data into house of quality matrix, specific transformers titles have been inserted on the left and the calculated weighs on the right. Fuzzy analytic hierarchical process (FAHP) has been implemented for weighing quality requirements.

Super Decisions software is powerful decision-making software. Using fuzzy scales and performing non-linear analyses are among the capabilities of this software. This software has been used to calculate research permanence or second questionnaire adaptation coefficient.

Chang method stages for fuzzy analytic hierarchical process (FAHP) are as following: 1) hierarchical diagram delineation; 2) fuzzy numbers definition for bilateral comparisons; 3) bilateral comparison matrix formation ($\tilde{A}$) using fuzzy numbers; 4) S_i (greatness degree) calculation in all bilateral comparison matrix rows; 5) S_i greatness degree calculation compared teach other; 6) criterions and alternatives weighs calculation in bilateral comparison matrixes; 7) final weigh vector calculation (Tzong-Rulee & Thiphuong, 2012).

To weigh customers requirements, the following stages are precisely followed (Atayee, M, 2010):

Stage (1): hierarchical diagram delineation

customer quality requirements have been extracted using comprehensive ISQ questionnaires. So, the hierarchical structure of this research consists of the following levels:

level(1): objective (best transformer selection); level(2): customers' quality requirements consisting of the following ten factors: need for maintenance, volume, age, weight, price, transformer immunity to burning out(disruption), transformer environment's immunity to fire, capability of working in polluted environments, transformer preparation time for being delivered to customers, voltage variations(demonstrated with C_1 to C_{10} in the table). Level (3): six research alternatives as following: gas-filled hermetic transformers, oil-immersed hermetic transformers, transformers with conservator, dry transformers, auto- transformers and shell type transformers (demonstrated as A_1 to A_6 in the table).

Stage (2): fuzzy numbers definition for bilateral comparisons

Stage (3): bilateral comparison matrix formation using fuzzy numbers

In this section of the matrix, alternatives are bilaterally compared with quality requirements. it is worth mentioning that since all research population experts are not familiar with specific transformers and technical characteristics are considered in this study, the numbers used in bilateral comparisons matrix and house of quality matrix are based on the most used items or mode. Due to diversity of data for each comparison, using average method would have led to long process. Experts' theories in this study are technical rather than behavioral or humanistic. So, these theories are not different among people. So, the most greed theories are considered as basic ones.

So, bilateral comparison matrix is as following:

$$\tilde{A} = \begin{bmatrix} 1 \tilde{a}_{12} \dots \tilde{a}_{1n} \\ \tilde{a}_{21} 1 \dots \tilde{a}_{2n} \\ \vdots \quad \vdots \quad \ddots \quad \vdots \\ \tilde{a}_{n1} \tilde{a}_{n2} \dots 1 \end{bmatrix}$$

This matrix consists of the following fuzzy numbers:

$$\tilde{a}_{ij} = \begin{cases} 1 & i = j \\ \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9} \;\; or \;\; \tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & i \neq j \end{cases}$$

Stage (4): S_i calculation for all rows of the bilateral comparison matrix

Being a triangular fuzzy number, S_i is calculated using the following equation:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$$

Where; i is row number and j is column number. M_9^{ij} are triangular fuzzy numbers of bilateral comparison matrixes. The amounts of $\sum_{j=1}^{m} M_{gi}^{j}$, $\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}$, and $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ are calculated from the following formula, respectively:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l, \sum_{j=1}^{m} m, \sum_{j=1}^{m} u_j\right)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right)$$

In these equations; l_i, m_i and u_i are the first, the second and the third variables of fuzzy numbers.

Stage (5): calculating the greatness degrees of S_is compared to each other

Generally, if $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, M_2 greatness degree compared to M_1 is defined as:

$$V(M_2 \geqslant M_1) = \mu_{M_2}(d) = \begin{cases} 1 & if \quad m_2 \geqslant m_1 \\ 0 & if \quad l_1 \geqslant u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & Otherwise \end{cases}$$

On the other hand, fuzzy triangular greatness degree of one number from other K fuzzy triangular numbers is calculated as following:

$$V(M \geqslant M_1, M_2, \dots M_k) = V[(M \geqslant M_1) and (M \geqslant M_2) and \dots and\ (M \geqslant M_k)]$$

Stage (6): criterions and alternatives weights calculation in bilateral comparison matrixes

In this regard, the following formula is implemented:

$$\acute{d}(A_i) = Min\, V(S_i \geqslant S_k)\ k = 1, 2, \dots, n, k \neq i$$

So, the un normalized weight vector is demonstrated as following:

$$\acute{W} = (\acute{d}(A_1), \acute{d}(A_2), \dots, \acute{d}(A_n))^T A_i (i = 1, 2, \dots, n)$$

Stage (7): final weight vector calculation

To calculate final weight vector, the weight vector must be normalized calculated at the previous stage so:

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T$$

After calculating the final weight vector, the result is inserted into the house of quality matrix as the final weight of customers' requirements.

The fuzzy numbers calculated by third questionnaire are inserted on the roof of house of quality matrix. These numbers are changed into di-fuzzy numbers, for facilitation.

The fuzzy numbers calculated by forth questionnaire are inserted in the body of the house of quality matrix. They are changed into di-fuzzy numbers, to.

Output weights of the house of quality matrix are the prioritized designation requirements.

Finally, 40 TRIZ principles have been used for detecting the contradictions between designation variables and their surrounding environments. The contradiction matrix table is used in this regard.

Super decisions software is implemented for hierarchical analysis of questionnaires permanence, using conforming coefficient. Cronbach's alpha coefficient was not use in this research since this coefficient is mainly used for calculating reliability of behavioral studies while the current research aims at technical investigation of transformers characteristics. If conforming coefficient value is less than 0/1, research permanence is approved. Conforming coefficients of all bilateral comparison matrixes are demonstrated in table (1).

Table (1): criterions' conforming coefficients

Criterion Matrix	**Conforming Coefficients**
comparison between self criteria	0/09
need for maintenance	0/05
Volume	0/07
Age	0/07
Weight	0/08
Price	0/06
Transformer immunity to burning out (disruption)	0/07
transformer environment's immunity to fire	0/01
capability of working in polluted environments	0/04
Transformer preparation time for being delivered to customers	0/04
voltage variations	0/06

As demonstrated in table (1), conforming coefficients of all parameters are less than 0/1. So, the current research is reliable. By considering that bilateral comparison isn't apply in other questionnaire, the comfortable coefficient isn't used.

5- Data analysis

FAHP operation results are demonstrated in table (2).

As demonstrated in table (2), dry-type transformers are the weightiest.

Table (2): calculation of specific transformers' final weights;

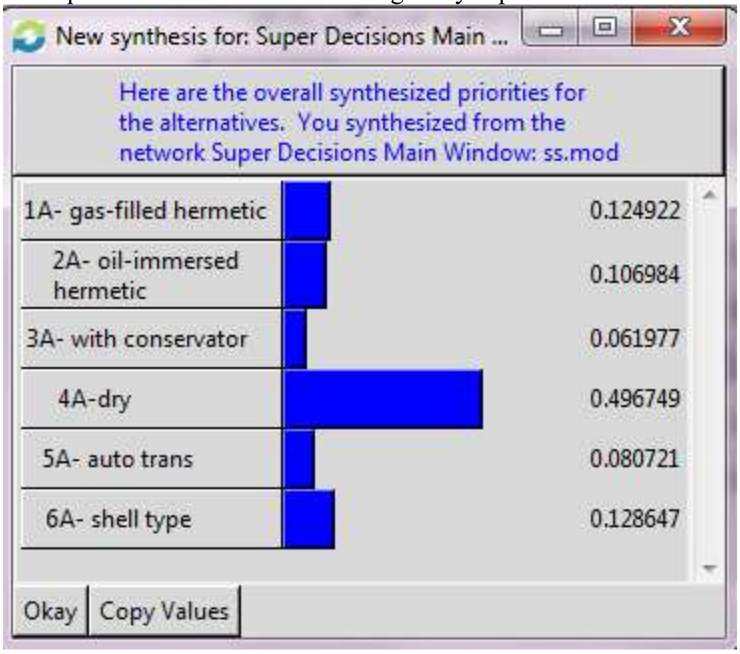
Sum	C_{10}	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2	C_1	
	0	0/099	0/231	0/113	0/034	0/112	0/09	0/132	0/161	0/024	W
0/126	0/021	0/345	0/189	0/012	0	0/184	0/223	0	0/018	0/143	A_1
0/103	0/295	0/182	0/175	0	0	0/165	0/217	0	0/018	0/153	A_2
0/068	0	0/072	0/09	0	0	0/036	0	0	0/224	0	A_3
0/472	0/636	0/351	0/189	0/987	1	0/354	0/271	0/859	0/39	0/327	A_4
0/063	0/045	0	0/165	0	0	0	0	0/14	0	0/271	A_5
0/161	0	0/048	0/189	0	0	0/26	0/287	0	0/348	0/102	A_6

Using questionnaires 3 & 4, bilateral relationships between technical requirements and each specific transformer effect on technical requirements changes were detected. Results obtained from questionnaires have been inserted into the house of quality matrix. Then, fuzzy numbers of the house of quality matrix are defuzzied through the following formula:

$$(a + ۴b + c)/_۶$$

The final weight is calculated by Super Decisions software, and it is considered that the calculated weights with software are equal to the weights of table (2) in first decimal. In other words the results that are extracted from the software are similar to those that are emerged by Chang method. this results led to decide to apply the weights that are calculated with software in continuation of calculating operations, due to high precise of software.

Table (3): calculation of specific transformers' final weights by super decisions software



So in the house of quality matrix, W_i^* is the relative importance of specific transformers based on customer requirements calculated by the software. Furthermore, RI_j and RI_j^* are defined as following (Khademi – Zare & Zarei, 2010):

$$RI_j = \sum_{i=1}^{n} W_i^* \times R_{ij}$$

$$RI_j^* = RI_j + \sum_{k=j} T_{kj} \times \mathrm{RI_k}$$

Where; RI_j in the quality house relationships matrix reveals the relations and effects of specific transformers on technical requirements' designation. RI_k is ... relative importance of the K_{th} technical requirement and T_{kj} is the correlation coefficient between the K_{th} and the J_{th} technical requirements on the roof of the house of quality matrix. the result obtained from RI_j^* is the technical parameters' final importance.

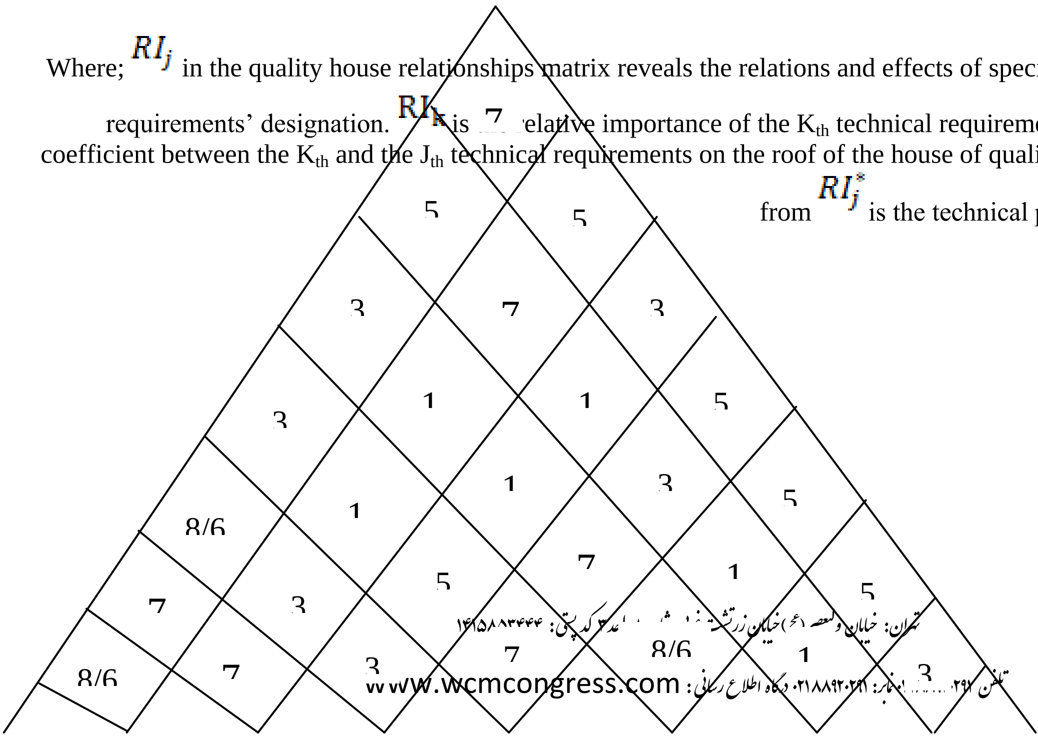


figure (3): completion process of the house of quality matrix

In the house of quality matrix output, customers' requirements priorities for specific transformers' designations are reflected on the right. So, the first research question is answered. In fact, customers' quality requirements were first detected as qualitative characteristics such as volume, price, immunity and etc, using open ISQ questionnaires filled by experts. It was revealed that specific transformers change qualitative parameters. Specific transformer types were recognized by using ISQ questionnaires. Then, specific questionnaires were prioritized based on customer requirements,

	current intensity	load losses	coil length	trans power	core cross-sectional area	No load losses	Coil type	Body type	W_i^*
gas-filled hermetic transformers	7	5	3	7	7	3	3	7	0/124
oil-immersed hermetic transformers	7	5	3	7	7	3	3	7	0/106
transformers with conservator	5	3	3	3	3	3	3	7	0/061
dry transformers	3	5	3	3	3	3	7	7	0/496
auto-transformers	7	7	7	7	1	1	5	3	0/08
shell type transformers	7	7	5	3	3	3	1	3	0/129
RI_j	4/866	5/276	3/566	4/228	3/748	2/828	4/874	6/136	
RI_j^*	199/182	156/435	132/094	164/227	131/092	123/875	107/37	145/198	

using FAHP process.

As revealed, in the lower output of the house of quality matrix; the three technical parameters (current intensity, trans power and load losses) are of the highest priorities, respectively. so, the second research question regarding prioritization of the product designations' technical requirements is answered.

But, how direct or indirect relationships between technical requirements and their environmental components are recognized? ISQ has helped experts to realize these relationships more comprehensively. The three parameters- current intensity and trans power and load losses- have positive relationship with each other. Increase in the first two parameters is favorite but increase in the third parameter is not favorite. Based on 39 TRIZ parameters, the two ameliorating parameters- current intensity and trans power- are considered as pressure parameters. On the other hand, the deteriorating parameter – load losses- is considered as energy loss parameter. To resolve this conflict, it must be referred to the technical contradiction matrix table and use the 36th parameter-fuzz change principle. Based on this principle, fuzz change effects such as volume change are applicable effects. So, it is possible to minimize energy loss by maximizing coil cross-sectional area. The following table's column reveals the contradiction resolving matrix. The right column and the upper row reveal

ameliorating and deteriorating parameters, respectively. The number indicting the two parameters' overlapping section reveals the contradiction resolving principle.

Table (4): resolving conflicts using contradictions matrix

	Deteriorating parameter			
Ameliorating parameter		. . .	energy	. . .
	. . .			
	pressure		Principle 36	
	. . .			

By increasing the coil cross-sectional area, more core capacity will be occupied and this will increase core cross-sectional area. Based on the house of quality matrix output; after coil length, core cross-sectional area and No load losses are the most important priorities, respectively. There is a negative relationship between core cross-sectional area and No load losses.

So, there is no opposition between core cross-sectional area and No load losses. But, the immobile objects volume increase- caused by core cross-sectional area increase- results in it's length increase that it shows more space occupation. Having considered the immobile object volume and object length increase as ameliorating and deteriorating parameters, they can be referred to the 14th principle of the contradiction resolving matrix-core spheration- and the conflicts can be resolved. The sphere core will occupy less capacity.

Table (5): resolving conflicts using contradictions matrix

	Deteriorating parameter			
Ameliorating parameter		. . .	Immobile object length	. . .
	. . .			
	immobile object volume		Principle 14	
	. . .			

So, the third and the fourth questions, regarding detection and solution of the conflicts between trans technical requirements using TRIZ instrument, are answered.

6- Discussion and conclusion

This research mainly aims at maximizing product designation processes efficiency. This research provides experts with an instrument for systematizing product designation process and resolving designation conflicts. This research is applicable in different aspects. Using QFD helped the authors to translate quality requirements, that might be difficult for engineers in understanding and applying them in modifying designing process. application of AHP led to weight variety of products based on criteria of customers with more preciseness and Fuzzy logic, also strengthened this preciseness by solving vagueness of linguistics. The results showed that practicability of technical requirements that were identified based on customer requirements , was in light of the instrument that solved conflicts between these requirements in shortest time, because of the competitive environment. This instrument was TRIZ. So, this research proposes methods for minimizing the arrival process to accurate designation period time and increasing efficiency. By minimizing time loss, the objective of transformer designation can be fulfilled. Due to the fact that fuzzy scale has been implemented in this study, the obtained results were more precise than those obtained in normal situations.

To increase efficiency, the cost factor was considered, because one parameter involved in the customers' quality requirements prioritization was price. This factor was considered in this research. To resolve technical requirements conflicts, some suggestions were provided using TRIZ for decreasing load losses or no load losses that these suggestions were indicator of preventing energy loss and excessive costs.

The research propositions are as following:

1- Implementing a combination of QFD and TRIZ in service industry to fulfill the main objective of "using innovative solutions in this industry".

2- Using a combination of TRIZ and data envelopment analysis model. by Detecting inefficient sections, data envelopment analysis model helps detecting system contradictions.

3- This research has aimed at resolving technical conflicts at the first stage of the house of quality matrix process. At this stage, designation technical requirements are recognized based on final customers' qualitative characteristics. So, it is proposed that researchers implement a combination of QFD and TRIZ at the other stages of the matrix.

4- Expanding value engineering by conducting operational researches using TRIZ.

Considering the fact that this research aims at ranking specific transformers and resolving their technical conflicts, it makes that research population is small. This is due to the fact that the number of experts familiar with specific transformers is very limited. Furthermore, each expert was familiar with a limited number of transformers and not all of them. Questionnaire designation is a demanding task. It involves specialized aspects. Furthermore, participants' justification is a difficult process.

The other limitation of this study is that it does not focus on the other transformer producer companies except Transfo. To gather data concerning customers' interests, designation and sale experts have been employed since customers could not be contacted directly.

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