Abstract

Consumer demand is the fundamental driving force of innovation; however, innovation is also an important way to quickly implement consumer demand. Innovative approaches to TRIZ as a science academia and the business community has been highly valued, but there is an objective bottleneck which the consumer demand is difficult to obtain. But consumer needs can be understudied and grasped by building QFD house of quality. Based on this, a new integrated innovation of TRIZ and QFD design methods have been proposed. As for the inherent ambiguity of consumer demand, the use of rough set algorithm for establishing decision-making model to build consumer demand for quality housing. Get through the house of quality parameters related to the design parameters and the contradiction between the theory and use of TRIZ tools to solve the contradiction between the design parameters. Finally, the feasibility and effectiveness of the method has been established by a case study.

Keyword: Management Engineering; Innovation Design; Rough Set; Triz; Qfd

1. Introduction

The important strategic task of China's economic structural adjustment and economic growth mode transformation is to enhance capability of independent innovation. However, the scientific innovation is the foundation and guarantee to enhance the capability of independent innovation. TRIZ revealed the internal laws and principles of the invention, which focused on clarifying and emphasizing the existed contradictions in the system, its goal was to completely resolve the conflicts to get the final ideal solution. Practice had proved that the use of TRIZ theory can speed up the process of invention and get high-quality innovation products [1]. However, it was still inadequate, there was not an objective for consumer demand and could not accurately obtain the design parameters bottleneck. QFD can complement the shortage of the TRIZ[2]. QFD was the multi-level analysis method which translated the consumer demand into innovation design; it also was the specific application in innovative design process [3]. The consumer demand was obtained more accurately through the House of Quality, and demanded mapping project design parameters [4]. In the Quality of house building the process, consumer demand was usually expressed with more vague language, such as better product quality, durability and good, there also existed disadvantages. Meanwhile, there were not enough objective problems in consumer decision-making.

The AHP, fuzzy sets and rough sets and other quantitative research methods were used to resolve the main decision-making of consumer demand.

The AHP was proposed by a at the U.S. operations research professor TL Saaty in the early 1970s [5]. It was characterized by the complex problems in a variety of interrelated factors into orderly layers, so principled. The AHP integrated expert opinion and results of objective analysis together which followed the subjective determine structure in the objective reality. Using the AHP needed to get the accurate consumer demand information, which may lead to tedious calculations and determine
deviation [6,7]. Fuzzy set theory was proposed by the U.S. automatic control expert Professor L. Zadeh [8]. It was an extension of classical set theory, which has been successfully used in many areas. The basic idea was the classic collection of affiliation to be expanded, so that elements of the collection of membership from the classic collection could only take two values 0 and 1, but the fuzzy set theory could be extended to take any number in the unit interval [0,1] which in order to achieved quantitatively characterize the uncertainty of consumer demand [9-11]. Although the use of fuzzy algorithm could be more accurate evaluation of consumer demand, but it needed to build a pre-membership function, the process of building a membership function was to rely on more experience, which also affected the objectivity of decision making on consumer demand.

The rough set theory was put forward as a mathematical tool for dealing with uncertainty by Professor Pawlak in 1982 [12]. In recent years, as a relatively new soft computing method, the rough set was paid more and more attention, which effectiveness was confirmed in many scientific and engineering fields application. In the use of rough sets to make decisions in consumer demand, the main idea was to conduct investigations of consumer demand to build decision-making system, then the use of rough set algorithm to evaluated consumer demand and reduction [13-16]. The rough set was different from AHP, fuzzy set theory and probability-based evidence, which did not require such as probability distributions, a priori knowledge of the membership function, so the rough set was more objective of consumer demand evaluation. However, the traditional rough set algorithm existed drawbacks of tedious calculations. In order to ensure the objective and accurate assessment, the consumer demand in the information table must be exhaustive, so the traditional rough set algorithm was not realistic.

In recent years, the integration of TRIZ and QFD had been explored by domestic and international researchers. To integrated QFD, functional analysis, the conflict matrix in TRIZ and the separation principle together. Ruihua Tan proposed the conception design which resolved not only the technical conflict in design but also the physical conflict[17]. The integration of QFD, TRIZ and Taguchi method was applied to product design and innovation by Xinjun Zhao [18].Yuanguan She built the problem-solving model of TRIZ and QFD integration [19]. These studies demonstrated the integration of TRIZ and QFD which solved the innovative design problem only from the macro enables, but did not give a specific approach to building quality homes, and how to use TRIZ tools to solve the contradiction between the design parameters.

Based on this, this paper presents a new integration of TRIZ and QFD innovative design approach. The method for the inherent uncertainty of consumer demand, using the idea of quality homes, the establishment of rough clustering hierarchical decision-making model to an important degree of consumer demand for order, and to identify the contradictions between the various design parameters, the final adoption of TRIZ contradiction matrix and 40 inventive principles to resolve the conflict between the design parameters to achieve innovative design purposes.

2. TRIZ and QFD Integrated Innovation Model

TRIZ and QFD integrated information model solve” what to do” and” how to do” in innovation, both the integrated innovation model can be described as shown in Figure 4. The process can be described as: first through the QFD house of quality, technology, ASI model, functional decomposition and technology system among TRIZ evolution theory to determine in product innovation, management innovation, service innovation, new features in the system. Then the material - field model and 39 engineering parameters can be used to describe the function of decomposition the problem is converted to TRIZ problem. Second, the function is decomposed to determine whether there was contradiction can be used if there is no contradiction among the 76 standard solutions of TRIZ, ARIZ algorithm, scientific methods and tools for knowledge base effect to achieve the system's new features. If there are contradictions, the contradiction matrix used to determine the corresponding solving technical contradictions inventive principles, separate principle used to determine the appropriate inventive principles of physical conflict, and finally the conflict is resolved using 76 standard solutions, ARIZ algorithm, other scientific effect knowledge base methods and tools to implement new features in the system to achieve the purpose of innovation.

Through the QFD by TRIZ integrated innovation model can be seen, a series methods and tools of
TRIZ can solve the problems of product design, technology, management system, service system which offered by the QFD. To achieve the purposes of product innovation, management innovation, service innovation and organizational innovation by solving the problems.

3. Consumer demand decision algorithm

In order of importance about User demand is achieved by using the rough set algorithm implementation. Rough Set theory is proposed by Professor Pawlak in 1982, which following probability theory, fuzzy sets, and evidence theory after another mathematical tool to deal with uncertainty. Rough set is different form fuzzy sets and evidence theory, it does require priori knowledge, and as a result it is more objective.
3.1 Algorithm Related Definition

A decision system $M$ can be formally expressed as quaternion $M = (U, At, \{V_a \mid a \in At\}, \{I_a \mid a \in A_i\})$. $U$ is a finite non-empty collection of objects, also known as the domain, $A_i$ is a finite non-empty set of attributes. $V_a$ indicates that the property $a \in A_i$, the range of attribute values, that attribute $a$ of the range, $I_a : U \rightarrow V_a$ is an information function. If $A \subseteq A_i$, then $I_a (x)$ shows the object $x$ of property value on property $A$.

Write $\phi$ as a formula for decision-making $M$, and the set $m(\phi) = \{x \in U \mid x \models_\phi \}$ as the meaning of $\phi$ in $M$. The argument of $m(\phi)$ is formula Language, which value is a subset of a collection of objects in information sheet. $m(\phi)$ is the object of all which has the character of formula $\phi$.

Using $L (A)$ indicates the language which was defined by attribute subset $A$. Considering the attribute subset $A \subseteq A_i$ and the corresponding language $X$, it can be defined the set of formal definitions are as follows.

Definition 1 In decision-making system $M$, if the said sub-set $X \subseteq U$ is an attributed subset $A \subseteq A_i$ can be defined, and only if there is a formula $\phi$ in the language $L (A)$ allows $X = m(\phi)$. Otherwise, it was not defined. Definable set of all expressed as: $\text{Def}(U, L (A)) = \{m(\phi) \mid \phi \in L (A)\}$.

Definition 2 If the two objects in the language $L (A)$ described by the same formula, or their individual property values on $A$ are the same, claiming that the two objects are equivalent.

Definition 3 Let $E(A)$ be an equivalence relation on $M$, $X \subseteq U$, the upper and lower approximation operators $\overline{apr}(E(A))$, $\underline{apr}(E(A))$ is defined as:

$$\overline{apr}(X) = \bigcup \{Y \mid Y \subseteq U, Y \cap X \neq \emptyset, Y \notin \sigma(U / E(A)) \}$$
$$= \bigcap \{Y \mid Y \subseteq U, Y \notin \text{Def}(U, L (A)), X \subseteq Y \};$$
$$\underline{apr}(X) = \bigcup \{Y \mid Y \subseteq U, Y \notin \sigma(U / E(A)) \}$$
$$= \bigcup \{Y \mid Y \subseteq U, Y \notin \text{Def}(U, L (A)), X \subseteq Y \}.$$ 

On the approximation of $\overline{apr}(X)$ is the least definable set containing $X$, $\underline{apr}(X)$ is included under the approximation of the maximum can be defined in the $X$ set.

Definition 4 Consider the subset $X \subseteq U$, the domain space will be divided into three areas:

1. Positive region of set $X : POS(X) = \overline{apr}(X)$;
2. Negative region of set $X : NEG(X) = POS(\sim X) = U - \overline{apr}(X)$;
3. Boundary region of set $X : BND(X) = \overline{apr}(X) - \underline{apr}(X)$.

If $BND(X)$ is the empty set, we called set $X$ about relationship $E(A)$ is clear (crisp); the other hand, if $BND(X)$ is not an empty set, we called set $X$ about relationship $E(A)$ is rough (rough).
3.2 Importance Sorting Algorithm of User Needs

Suppose there are $N$ user survey, user needs expressed by $CR$, with $m$ a user needs, the user needs is: $CR = [CR_1, CR_2, \ldots CR_m]$, the customer satisfaction expressed by $CS$.

Step1 Construct a definition of rough set decision table $M$. Constitute the object of different combinations of demand for $U$, user needs $CR$ indicate condition attributes, and user satisfaction $CS$ said the decision attribute, the user survey results for the property value, which means that the user needs with a set of attributes $A$, $B$ said that customer satisfaction with a collection of properties.

Step2 According to the definition of relative positive region, $POS_A(B)$ is equal to $POS(B)$ by calculating the individual needs to determine whether reduction. If $POS_A(B) = POS(B)$, this shows that a user needs and satisfaction of $CS$ relative to $CR_i$ is reduction.

Step3 Using $\lambda_j$ indicates the conditions of access to the important properties of $CR_j$ degrees which obtained from customer survey $j$.

$$\lambda_j = \frac{POS_A(B)}{|U|} - \frac{POS(B)}{|U|}$$

Step4 Using $\lambda_i$ indicates the importance of condition attributes $CR_i$.

$$\lambda_i = \frac{\sum \lambda_j}{n}$$

4. Parameters of the framework to resolve conflicts

The use of TRIZ methods and tools of these parameters to resolve the contradictions in the framework map as shown in Figure 2:
Figure 2. the framework of using TRIZ to resolve parameters contradictions

The process of using TRIZ to resolve parameters contradictions can be described as: first of all, through the concept of HOQ products designed to determine the technical parameters, then uses some of 39 common engineering parameters to express problem to be resolved, so a specific problem will be changed into the TRIZ’s problem; second, to determine the TRIZ problem are technical conflicts or physical contradictions. If it is technical contradictions, conflicts on the use of matrix from the 40 principles of the invention which is suited to find the principle, if it is physical contradictions, we can use the separation principle to determine the adapted principles of the invention; Finally, through the invention of the principle to find the incidence of specific problems, and the evaluation of the program, if satisfied with the program feasible, we can execute the program; if the program is not feasible, we must duplicate all the steps until you find satisfaction with the feasible solution as so far.

5. Example

Use the mobile phone product design to verify the presented method.

Step 1 To sort important degree of consumer demand

Assume that two user surveys, user demand for \( CR = \text{[phone appearance (} CR_1 \text{), standby time (} CR_2 \text{), multimedia functions (} CR_3 \text{)]} \). Empirical research using Likert 5 score scale[20] to evaluate the customer satisfaction. Evaluate set \( V = \{v_1, v_2, v_3, v_4, v_5\} \).
\( v_1 = 1 \cdot v_1 = 2 \cdot v_1 = 3 \cdot v_1 = 4 \cdot v_1 = 5 \). To build the decision table based on the user researching.

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By calculating the relative positive region to determine the various needs of customer satisfaction whether it can be redacted or not.

The relative positive region \( CR_i \) of user A is:
The relative positive region \( CR_2 \) of user A is:

\[
POS(B)_{A} = \{ \{U_{1},U_{13}\}, \{U_{37},U_{49}\}, \{U_{14},U_{26}\}, \{U_{18},U_{30},U_{42}\}, \\
\{U_{27},U_{39}\}, \{U_{16},U_{28}\}, \{U_{40},U_{52}\}, \{U_{44},U_{56}\}, \{U_{24},U_{36}\}, \{U_{48},U_{60}\}, \\
\{U_{19},U_{31}\}, \{U_{20},U_{32}\}, \{U_{29},U_{41},U_{53}\}, \{U_{45},U_{57}\}, \{U_{34},U_{46}\}, \{U_{35},U_{47}\}\}
\]

The relative positive region \( CR_3 \) of user A is:

\[
POS(B)_{A} = \{ \{U_{1},U_{4}\}, \{U_{2},U_{5}\}, \{U_{3},U_{6},U_{8}\}, \{U_{7},U_{9}\}, \{U_{10},U_{12}\}, \{U_{19},U_{21}\}, \\
\{U_{14},U_{17}\}, \{U_{18},U_{20},U_{22}\}, \{U_{25},U_{28}\}, \{U_{27},U_{30},U_{32}\}, \{U_{34},U_{36}\}, \{U_{37},U_{40}\}, \\
\{U_{38},U_{41}\}, \{U_{39},U_{42}\}, \{U_{44},U_{46}\}, \{U_{49},U_{52}\}, \{U_{55},U_{57}\}, \{U_{51},U_{54},U_{56}\}, \{U_{58},U_{60}\}\}
\]

The relative positive region \( CR_3 \) of user A is:

\[
POS(B)_{A} = \{ \{U_{1},U_{2},U_{3}\}, \{U_{4},U_{5},U_{6}\}, \{U_{7},U_{8}\}, \{U_{11},U_{12}\}, \\
\{U_{14},U_{15}\}, \{U_{16},U_{17}\}, \{U_{25},U_{26}\}, \{U_{29},U_{30}\}, \{U_{35},U_{36}\}, \{U_{37},U_{38},U_{39}\}, \\
\{U_{40},U_{41},U_{42}\}, \{U_{43},U_{46}\}, \{U_{50},U_{51}\}, \{U_{52},U_{53}\}, \{U_{55},U_{56}\}, \{U_{59},U_{60}\}\}
\]

Because \( POS_A(B) \neq POS(B)_A \) and \( POS_A(B) \neq POS(B)_A \), the requirements \( CR_1, CR_2 \) and \( CR_3 \) of user A can not be redacted relative to \( CS \). Similarly, the needs \( CR_1, CR_2 \) and \( CR_3 \) of user B with respect to \( CS \) are also not be redacted.

Calculate the importance needs of the user A and user B.

As to user A, the importance of \( CR_1, CR_2 \) and \( CR_3 \) are:

\[
\lambda_{1_A} = \frac{POS_A(B)}{|U|} - \frac{POS(B)}{|U|} = 1 - \frac{34}{60} = 0.433
\]

\[
\lambda_{2_A} = \frac{POS_A(B)}{|U|} - \frac{POS(B)}{|U|} = 1 - \frac{42}{60} = 0.3
\]

\[
\lambda_{3_A} = \frac{POS_A(B)}{|U|} - \frac{POS(B)}{|U|} = 1 - \frac{36}{60} = 0.4
\]

Similarly, for user B, the importance \( \lambda_{1_B}, \lambda_{2_B} \) and \( \lambda_{3_B} \) of \( CR_1, CR_2 \) and \( CR_3 \) are 0.533, 0.45 and 0.183.

According to the formula the ultimate importance of computing needs.

\[
\lambda = \frac{\sum \lambda_i}{2} = \frac{\lambda_A + \lambda_B}{2} = 0.483
\]
Calculating from the known importance of the demand, the appearance of the mobile phone is the most important, the less important fact is standby time, the least important multimedia features.

Step 2 Obtain technical parameters and the contradiction between parameters

According to the needs of an important degree of sorting, texture and color of these two innovative consumer demands when making the system design should be given priority to meet. Technical requirements were: material selection design, color design. Because consumers needed the good texture phone, if selected aluminum-magnesium alloy material, the colors design of its color and surface plating coating changed to meet different consumer demands for mobile phone color shell. In the mobile phone design, the parameters could not be studied for ever it was related or not. This study was mainly about the situation of a negative correlation between parameters. When in selected the aluminum-magnesium alloy chassis as phone design, its main purpose was to show and highlight the high quality surface texture, so usually there would be no change in color design and more design, but if the phone in aluminum-magnesium alloy shell plating on the surface increase the surface color and plating, you could add different colors for the shell. However, it would increase the surface of aluminum-magnesium alloy casing materials processing costs and increase the manufacturing time.

Step 3 The parameter conflicts were resolved by using 40 separation principle and 39 engineering parameters of TRIZ contradiction matrix.

The striking contradiction of mobile phone design was got through the above steps: the conflict between the increasing aluminum-magnesium alloy casing cost and color design control. Through the TRIZ contradiction matrix and the expansion engineering parameters, the analysis was to improve the parameters (1) Shape: increase aesthetic appearance; (2) strength: use to change the shell plating color. The deterioration parameters (1) manufacturability: increase the difficulty of processing and processing costs; (2) loss time: increase processing time. The building TRIZ contradiction matrix as table 3:

<table>
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<th>Loss of time</th>
<th>Manufacturability</th>
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Eleven inventive principles could be got by the above tables. The invention principle was excluded through screening, and then got the useful invention principle 28: replace the mechanical systems - change the aluminum-magnesium alloy body, so that the aluminum-magnesium alloys chassis with more color on the visual experience. Or select other materials, such as Aluminum-magnesium alloy. Although aluminum-magnesium alloy material was light, the costs of materials were more expensive and difficult to change the appearance of color. Choose aluminum-magnesium alloy as an alternative, the basic material requirements to ensure consumers could also save costs and control the processing time.
6. Conclusion

TRIZ theory is the perfect combination of human technological knowledge and innovative thinking rules. It reveals the laws and principles of human innovation system, which provides a solid theoretical and methodological basis for better innovation, it also recognizes and promotes the activities of a human innovation breakthroughs. However, the existence of consumer demand can not be objective for the drawbacks; QFD can make an effective supplement. Based on this, this paper presents a TRIZ and QFD integrated and innovative ways. First, a new consumer demand which is established by using rough set can be more objective decision-making algorithm to grasp and understand consumer demand. Secondly, use of House of Quality in the idea to obtain design parameters and to determine the parameters of the conflict. Finally, the relevant principles and methods which are provided by the TRIZ theory to solve the contradiction between the design parameters achieve innovative design purposes. In this paper, empirical analysis demonstrates the usefulness of innovative design and effectiveness.

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8. References