Integration of QFD method and TRIZ tools in an innovant product development

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Abstract. As organizations strive to compete in the highly competitive global economy, the level of competition is intensifying, so that it requires developing new and improved products to meet specific customers' needs. This paper attempts to present a model that can be used for developing new products process, based on the integration of QFD method with TRIZ tools. In fact, we will use functional analysis, in order to clearly define customer's needs, before using QFD method which makes it possible to translate the process requirements into design features, through the House of Quality. However, some contradictions may arise between technical characteristics. Thus, a systematic analysis based on the TRIZ tool will be introduced, in order to withdraw many potential contradictions between technical requirements, or predict a potential evolution trend, via innovative solutions that meet design principles.
Keywords: QFD; TRIZ; House of Quality; Functional Analysis; New Product Development; CDCF; Contradiction; Evolution Trends; Innovation.

1 Introduction

Nowadays, globalization leads to a strong competition between companies, since the customer becomes more selective as far as choosing products is concerned. Thus, companies must go along with such a strong competition, through establishing a strategy that aims to provide attractive products to their respective markets, so that it gives a feeling of satisfaction to their customers, in terms of quality, outstanding functions, price, time, and service. Considering these conditions, original technical innovations through the development of advanced technologies become an indispensable factor to create new products.
In fact, the development of a new product is a knowledge-driven activity in which requirements and constraints are converted into a product description [1].
Theory of Creative Problem Solving (TRIZ), proposed by Genrich Altshuller [2], is a widely used method for solving creative problems and fostering innovation during the design process [3]. However, the use of TRIZ tools remains difficult, especially for non-experts. The main difficulty arises during the exploitation of TRIZ contradiction matrix. Several contradictions may emerge during this phase. It becomes difficult to identify the most relevant contradictions to handle. Dealing with all contradictions may be very time-

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consuming. Hmina et al. [4] proposed a preferences-based approach in order to prioritize these contradictions. Using desirability functions and an aggregation operator, the proposed approach aims to evaluate the effect of each contradiction on the achievement of design objectives. Trojan & Marçal [5] proposed using a multi-criteria decision-making aid method (ELECTRE) with different design criteria in order to prioritize identified contradictions. Ben Moallem et al. [6] proposed a qualitative approach to identify the most relevant contradictions. They proposed to conduct semi-structured interviews with expert to classify contradictions according to their importance.
QFD is generally used in order to capture the customer voice and, then, translate the process requirements into design features. Nevertheless, some other features are not expressed, since they reflect the evolutionary trends of the product. On the other hand, some contradictions may result, which needs many compromise solutions to achieve the optimal performance. The advantage of QFD is its ability to display potential contradictions in design requirements. Thus, the systematic analysis based on the Theory of Creative Problem Solving (TRIZ) was developed to propose innovative solutions that meet design principles.
This paper proposes a model of a product innovation process, based on the integration of QFD method with TRIZ tools. In the first step, the functional analysis is used in order to clearly define customer's needs through developing a CDCF and identifying service functions, and constraint ones. In the second section, QFD tool is applied via the house of quality matrix. It serves to classify users' requirements according to their importance, validate technical specifications that must be taken to satisfy customers' needs, and identify potential conflicts that might be occurred between them, and finally TRIZ method will be introduced, that aims to withdraw many potential contradictions between technical requirements, or perhaps predict a potential evolution of the final product, to enable the product conception.

2 Functional analysis

Functional analysis is a method that integrates the need that will mark the product characteristics, technical solutions to satisfy its requirements, as well as the topological analysis that lays the groundwork for the future product development [7]. It enables to characterize the functions offered by a product, in order to satisfy the user's needs. This method is used to analyze product before proceeding with realization, it allows studying the product as well as their constraints. Two stages have taken in functional analysis: the first one "external functional analysis" and second "internal functional analysis" [8].
The functional analysis of the need for a product, system or service basis resides in its potentiality to be valuable by satisfying the expecting benefits for future users. Indeed, it describes the user's point of view, as if the product is a «black box» that must meet expressed needs during its life cycle. For that, the graphical tool shown in figure 1, called "horned beast" is used to answer the following questions: At who/ what does the system serve? On who/what is he operating on? For what purpose? [7].

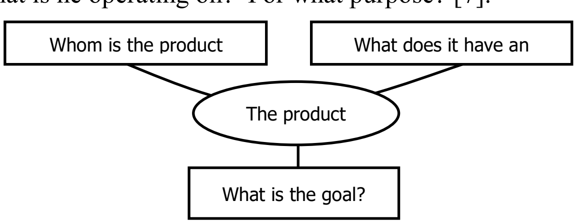


Fig. 1. Horned beast diagram [7]

Functions identification: This step is very important during a design process. Indeed, functions reflect the description of the need to be satisfied by the system and they guide for the use of the technical solutions to be later analyzed.
Functions of the system are represented via Octopus diagram, which introduces the system (component of study) surrounded by elements of external environment (A,B,C,D,E) shown in figure2,this external environment are linked together by functions (PF, CF1, CF2, CF3). In other words, the role of octopus's diagram is to define the relationships that might be between elements of the system environment. Thus, service functions, separated into main functions (PF), and constraint functions (CF) are defined. The figure 2 shows an example of the octopus diagram:

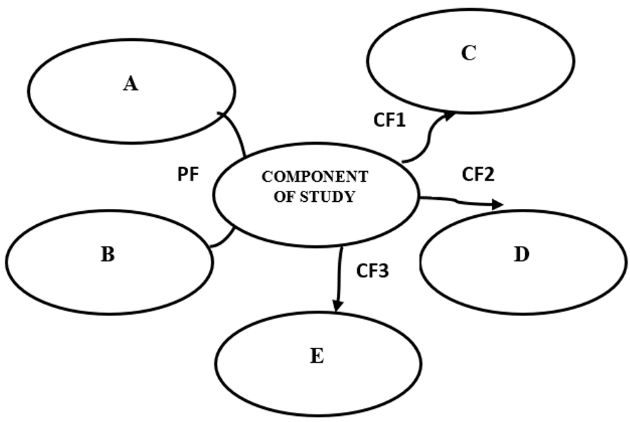


Fig. 2. Octopus diagram [7]

Technical-functional analysis: it aims at analyzing the system from the technical point of view. In fact, it ensures the transition from service functions to technical functions, before proposing constructive solutions that will be implemented. For this purpose, the FAST diagram makes it possible to well understand a complex product, and then introduce different scenarios of technical solutions, up to constituent equipment of the product, through answering the questions: Why? When? How? Starting from a given function.

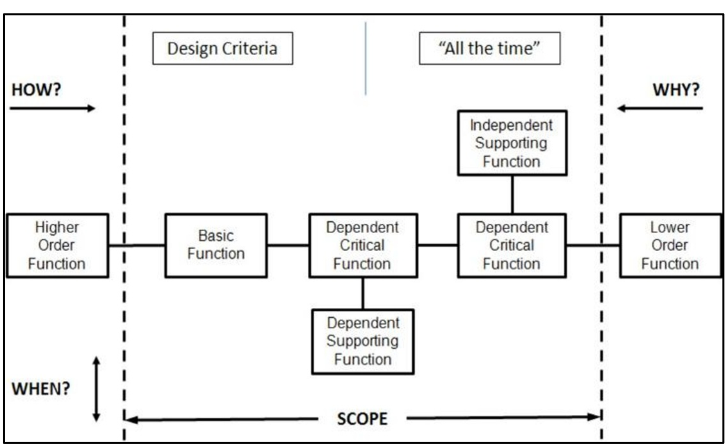


Fig. 3. FAST diagram principle

Also, the second tool that might be used is the SADT diagram shown in figure 4, which is an analytical tool that shows the functional relationships of the values computed by a system, including input and output values, as well as internal data stores. It represents data values flow from their sources through processes which transform them to their destinations in other objects and expose how this data are related to the outside world.

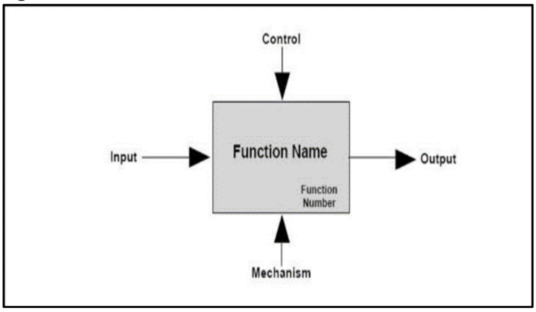


Fig. 4. SADT diagram

3 Quality Function Deployment – QFD

Quality Function Deployment (QFD) was founded by Akao Yoji in Japan in 1966 [9], he described this method as a systematic quality management approach, that aims at creating customers' satisfaction, through defining their requirements, and later convert them into design targets, from product planning and production process, to distribution to the targeted market [10] [11].
Indeed, The QFD methodology aims to achieve client satisfaction and take into consideration his voice in different steps of development and product [9], which needs more effort to get necessary information to reflect the customer's requirements [12]. For that a, different way and method are used to satisfy the client and understand his needs like: surveys, discussions or quiz [12] before convert customers' requirements into measurable design targets.
This method might be considered as a proactive product development, that promotes teamwork values within the organisation, and then it generates so many significant gains. Indeed, getting market information on a continuous basis through listening to customer's voice ensures a successful introduction of the product and its good position in the market place. Also, QFD may optimizes design process cycle time, since the product is introduced faster to the market. Moreover, the product quality is improved, as the lower number of required technical changes would absolutely reduce run-up costs and financial waste.

3.1 House of Quality

The deployment of product requirements, following users' expectations in regard to a specific product, is represented by a matrix diagram called "House of Quality". Indeed, it is considered as the essential tool of QFD, for decision making, since it is performed by different departments of a company (marketing, sales, design, production, quality…). Not only does the House of Quality reduce product development time, but it also, it increases the users' satisfaction once they use the product [10].
The House of Quality diagram brings to mind the shape of a house with a rooftop. It is about a series of successive steps that pinpoints the fact that the design of a product should reflect customers' needs, which are directly related to technical specifications and engineering characteristics. In fact, lines refer to customers' requirements, while columns contain expected technical characteristics of the product [13].

The figure 5 below shows the different part of the House of Quality Matrix:

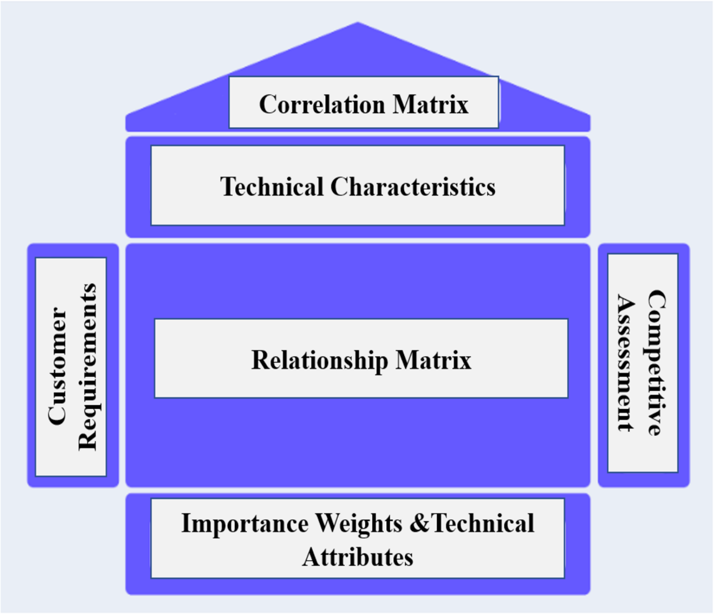


Fig. 5. House of Quality Matrix

The first step in of the House of Quality consists of defining customers' requirements.

- **Customers' Requirements**: The part in the left of the matrix, called also the "**What**". Needs of customers that are generally different, subjective and personal, are listed. They reflect their particular preferences for the product. They might be defined through many ways: interviews, customer complaints, market investigations, focus group and surveys, Then, each need is rated on a scale of 1 to 5, according to its importance [10].
- **Technical Characteristics:** Called also the "**How**". It presents controllable and measurable design requirements, engineering specifications and technical methods, that are directly related to the "**What**" section, and which they must be taken by the organization, so that customer's needs will be satisfied [10].
- **Relationship Matrix:** Each intersection between a «**What**» and a «**How**» is evaluated to determine if there is a relationship or how strong that relationship between defined customer's needs and technical characteristics is. For that purpose, the legend below is used [10]:

◎ =weight of 9, which means a strong relationship.
❍= weight of 3, which indicates a medium relationship.
△ = weight of 1, which refers to a weak relationship.

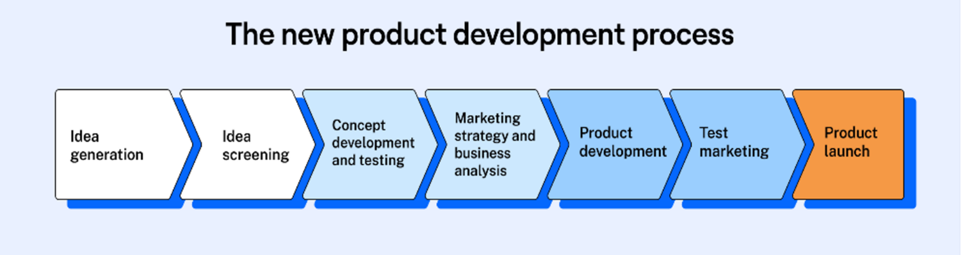
- **Correlation Matrix:** The top portion of the matrix, called also the **«Roof of the House».** Indeed, starting with identifying customers' requirements and then convert them into technical methods might generate some contradictions. This part introduces potential conflicts that may be occurred between technical specifications, via using symbols representing positive (+), strong positive correlation (++), negative (-) or strong negative relationships (--).
- **Importance Weights & Technical Attributes:** Importance weights represent the overall importance after evaluating both engineering relationships and customer importance. In

fact, for each technical specification, the importance weight is determined, through calculating the product of each customer's need rate value and the corresponding value of the relationship symbols in the legend used in relationship matrix part. Concerning the technical attributes, they define target values that should be used for each technical characteristic "How", as an objective way to ensure users' requirements.

- **Competitive Assessment:**. The right of the matrix shows the comparative assessment section. It is a sort of benchmark analysis in which a trending line indicates the position of the product compared to other brand models with similar specifications. For each customer specification, each brand is rated on a range of 1 up to 5. (1 refers to a poor effectiveness of the brand, 5 means excellent effectiveness of the brand).

4 New product development

New product development is a dynamic and global process that starts from idea generation until product launch step, and lasts with the evaluation of the product success. It is considered nowadays as a challenging business due to increased globalization, which enables firms to take advantage of worldwide opportunities, improve their efficiency and boost their effectiveness of innovation. In other words, developing new products is pretty related with companies needs to maintain a competitive advantage within the market. Indeed, new products process is quite difficult, since all different departments are involved to ensure the creation of a single product (business, product development, marketing, and sales…). Moreover, the new product viability at every stage of its development has become the primary focus of product managers, as radical innovation is crucial to the future product as well as the survival of the firm.



The new product development process can be summarized in figure 6 below:

Fig. 6. The new product development process

A new product development process can be described as follow:

- Idea generation: refers to using brainstorming methods, to introduce new products concepts or in order to improve existing ones, depending on market trends and customers' requirements evolution. Sources of generating ideas might be external via users' feedbacks, market studies, benchmark analysis, continues surveys. On the other hand, some ideas may be generated within the organization, marketing and sales services, technical department…

-Idea screening: as the second step, that consists of choosing ideas that will have the maximum probability of success. It is a critical step that needs the presence of multidisciplinary experts from different fields, in order to decide which idea to pursue.

-Concept development and testing: once the idea is chosen, it must be developed into concepts, which is a specific description of the idea, that must include features of the future products, technical solutions, required resources, estimated design and production costs, as well as proposed price.

-Marketing strategy and business analysis: it is a primordial step that aims at introducing the product to the targeted market through a marketing strategy. It will give a clear idea about the position of the new future product, evaluate its attractiveness in regards to many factors, such as expected price, sales expectations, and customer's appreciation.

-Product development: this stage comes one the last step is fulfilled. It means converting the concept into a finished product. This step consists of developing protypes under test by users to check their feedback, correct potential issues, validate the design, and ensure positive interactions towards the final product.

-Test marketing: it aims at evaluating the final product performance, by releasing it to a sample market, as a final validation before moving to product launch.

-Product launch: it represents the final step of the process. It refers to introducing the final product to the targeted market. One of key points of that important step is ensuring continuous track of the product success and plan necessary adjustments if ever needed.

5 TRIZ Method

TRIZ method was proposed by a Russian inventor, called "Genrich Altshuller" in 1946. TRIZ is a Russian acronym, that means "Theory of Inventive Problem Solving". It is considered as a problem-solving tool using a methodical approach that enables to find suitable solutions for complex problems, which generally need inventive solutions.[14]. Altshuller, analyzed more than 400 000 patents in order to draw 39 engineering parameters, identify 40 principles of innovation and elaborate the contradiction matrix. Indeed, this method helps to eliminate contradictions that might be occur during the product design.

01: mass of the moving object	14: resistance	27: reliability
02: mass of the static object	15: duration of action of the moving object	28: accuracy of measurement
03: length of the moving object	16: duration of action of the static object	29: manufacturing precision
04: length of the static object	17: temperature	30: harmful factor to the object
05: surface of the moving object	18: light intensity	31: harmful factors induced
06: static object surface	19: energy used by the moving object	32: ease of realization
07: volume of the moving object	20: energy used by the static object	33: ease of used usage
08: static object volume	21: power	34: maintenance
09: speed	22: loss of energy	35: adaptability
10: strength	23: loss of substance	36: product complexity
11: voltage, pressure	24: loss of information	37: complexity of the piloting
12: form	25: waste of time	38: degree of automation
13: stability of the object	26: amount of substance	39: productivity

Table 1. The 40 principles of innovation of the TRIZ theory [15]

1. The segmentation	2. The extraction
3. The local quality	4. The asymmetry
5. The combination	6. The universality
7. The pullout dolls	8. The Counterweight
9. The contrary action prerequisite	10. The anticipation
11. The prevention	12. The equipotential bonding
13. The alternative	14. The curvature
15. The Adaptability	16. The action reduced or excessive
17. The change of the dimension	18. Mechanical Vibration
19. The periodic action	20. The continuity of an action of usefulness
21. The quick action for security	22. The transformation of a detrimental effect in useful effect
23. The enslavement	24. The Intermediary
25. The self service	26. The Copy
27. The ephemeral cheap	28. The evolution of the mechanical system
29. The Fluids	30. The deformable,
31. The porous materials	32. The color change
33. The homogeneity	34. The rejection and regeneration
35. The change of ownership	36. The phase transition
37. The thermal expansion	38. The oxidation
39. The inert environment	40. The composite materials

Table 2. The 39 criteria for design [15]

In fact, the designer identifies the existing contradiction during the product design. Once the Problem is identified, it must be formulated into a standard or a general problem. Then, TRIZ tools are used in order to determine generic solutions, before convert them into specific solutions. The figure7 represents the general process of TRIZ method to identify specific solutions: [4]

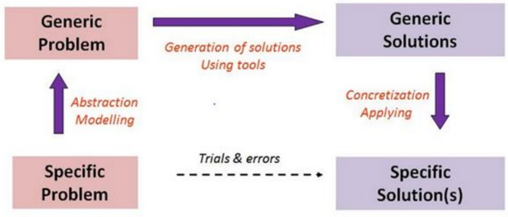
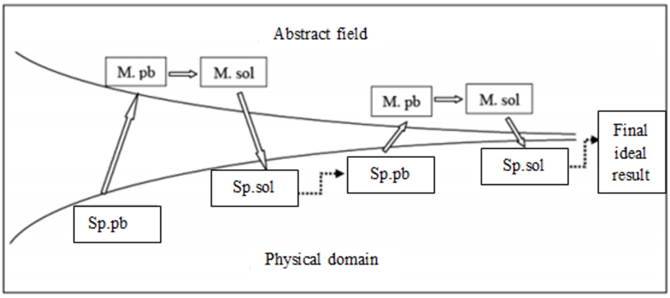


Fig. 7. The general process of TRIZ method [15]

The TRIZ approach proposes a detailed methodology that assist the user in identifying generic problems and later developing specific solutions, which are not generally the final innovative solutions. In fact, a specific solution might be origin of a new specific problem, for which new solutions must be defined. Thus, the chosen solution follows a converging process as shown in figure 8:



M.Pb	Modeling of Problem
M.Sol	Modeling of Solution
Sp.Pb	Specific Problem
Sp.Sol	Specific Solution

Fig. 8. Convergence of the approach of TRIZ [15]

6 The Proposed model

The process of the proposed model is shown below:

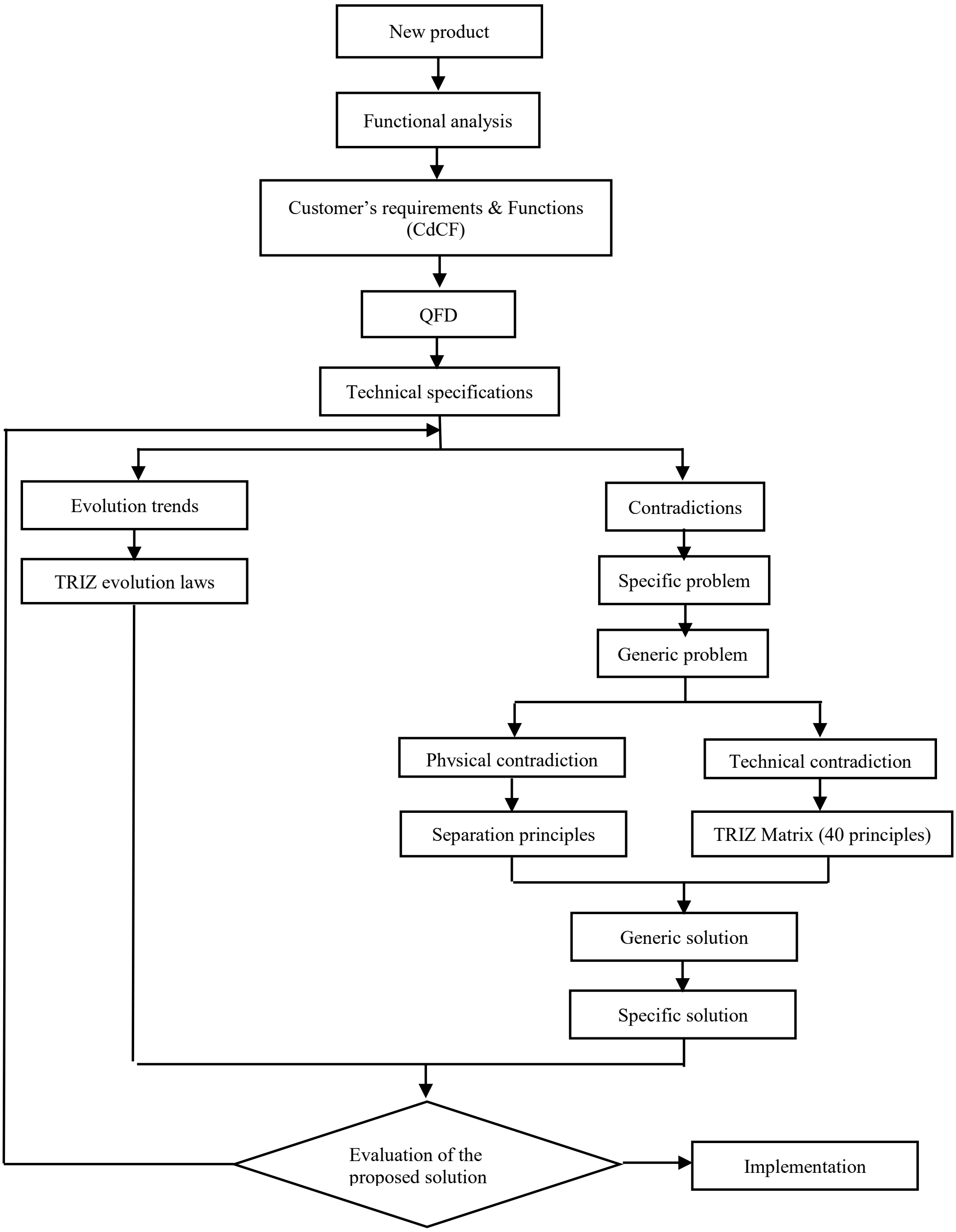


Fig. 9. Proposed model

The process of the proposed model is described as follows:

- The starting point of the proposed model refers to the conception of a new product idea or renewing an existing one, in order to be launched into the targeted market.
- Then, the next step consists of using Functional Analysis, as a primordial tool that aims at identifying system functions, describing needs to be fulfilled, as well as ensuring the transition from service functions, to technical ones, through introducing constructive solutions that should be implemented.
- Once customer's requirements are clearly identified via CdCF, the following step consists of using QFD tool, via the House of Quality matrix. In fact, customers' need will be listed in the left of the matrix, before rating them according to their importance. Then, we place expected technical characteristics, detailed engineering specifications, measurable design targets, that will fulfill users' needs, into the matrix columns.
- Afterwards, once technical specifications are set, correlations between them must be defined, in order to identify some contradictions that might occur, and which can affect some of the final product features. That's why TRIZ tools will be used. Indeed, specific problems must be well analyzed and understood, before formulating them as generic or standard problems. Actors may face two types of contradictions: technical contradictions, which are resolved via TRIZ matrix with 39 parameters & 40 principles of innovation, and physical contradictions that can be eliminated through the 4 separation principles, separation in terms of time or space.
- Therefore, TRIZ tools is used to determine generic solutions, before interpret them and draw specific solutions for the determined specific problem.
- Absolutely, QFD method is useful to identify relationships between technical specifications which can be sometimes only positive. Hence, actors look for some innovative ideas to ensure evolution trends of the product, as well as its potential development, through using the 8 TRIZ evolution laws. In fact, not only does TRIZ theory resolve contradictions, but also it helps to propose many evolution ideas, in order to ensure the continuous development of the product.
- Finally, the last step consists of evaluating proposed solutions, from both technical and financial points of view. Therefore, if the solution seems to be suitable and applicable, it well be implemented. Otherwise, iterative operation of using TRIZ tools remains necessary to propose again new potential specific solutions or identified specific problems.

7 Conclusion

It is crystal clear that new product development is a complex activity in which customer's delight while constraints satisfaction is a great challenge that firms have to overcome. In this paper we proposed a model of a new product development process in which QFD method and TRIZ tools are both integrated to come up with innovative solutions. Indeed, QFD method enables to track relationships among requirements, identify measurable engineering parameters and define potential interactions between them, via using the House of Quality. Besides, TRIZ power consists of offering innovative solutions that may promote the evolution of the product and its development process. In fact, TRIZ matrix with 40 principles eliminates technical contradictions, while separation principles resolve physical contradictions. Otherwise, if there are no contradictions, TRIZ evolution laws can be used to ensure evolution trends of the product, as well as its potential development, regardless of their nature. The proposed model is considered as a continuous cycle that might assist actors in finding the optimal solution to be implemented during the product development process.

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