*International Journal of*
*Operations Research*

International Journal of Operations Research Vol. 10, No. 2, 80−91 (2013)

# A Conceptual Design of a Mobile Healthcare Device-An Application of Three-stage QFD with ANP and TRIZ

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**Abstracts—** This research sets up a conceptual design of a future mobile or portable healthcare device using the quality function development (QFD) with the analytic network process (ANP) and the theory of inventive problem solving (TRIZ). We propose a three-stage QFD in order to consider customers' requirements, extend the whole design process, and calculate the priorities of the left-hand-side elements in the houses of quality (HOQ) by implanting ANP. Some contradictions at the roof of the second "house" are able to be overcome by TRIZ. Going through the integration of the three methods, the analysis results characterize the features and their priorities for the future mobile device. We believe that this conceptual design of the mobile healthcare device can provide a new direction to the healthcare industry.

***Keywords*** **—**Conceptual design; QFD; ANP; TRIZ Mobile healthcare device; House of quality.

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## 1. INTRODUCTION

With the impending aging population problem in many developed countries, the needs of healthcare are becoming more and more crucial. Due to technological developments in information and communication and the increasing demand for sophisticated healthcare, medical companies in many countries are now designing and developing healthcare devices that are smaller and lighter for personal use. For example, in 2012 Hidalgo, one of Cambridge Wireless' longest standing founder members, launched the Equivital EQ02 LifeMonitor, which is a small detection device that can detect, record, and transport users' health condition (Vivonoetics, 2013). As a result, the future trend of the medical technology and service industry is that users will be able to receive immediate healthcare services by carrying a mobile or portable healthcare device anywhere and to easily receive a telemedicine service. Therefore, the purpose of our research is to design a future concept of a mobile healthcare device by employing creative and innovative thinking and integrating product development methods in order to break through any limits and restrictions of design. We develop the general process of the conceptual design, which considers not only the customers' requirements, but also the product functions and the costs. This process can be applied to the conceptual design of many different areas and provide useful information to a research and development (R&D) department.

This paper proposes a product's conceptual design process that consists of three main methods: QFD (quality function development), ANP (analytic network process), and TRIZ (theory of inventive problem solving). QFD is a structured approach for integrating the "voice of the customers" into a new product design (Sullivan, 1986). We propose a sequence for house of quality (HOQ) with three stages or phases of development: product deployment, component deployment, and cost deployment for a better translation of the customers' requirements to the device design. We further consider ANP so as to prioritize the importance or weights for the left-hand-side items of the first two "houses" (or "what" items) for realizing their importance and possible interdependence. Some contradictions on the roof of the second "house" (or "how" items) are able to be overcome by TRIZ. The detailed process generates a feasible conceptual design draft of a mobile healthcare device for managing people's healthy condition anywhere in their daily life. In addition, we factor customer requirements into every aspect of the process.

Our mobile healthcare device combines many detectors, such as blood glucose meter, blood pressure meter, heartbeat detection, etc., and includes healthcare software that analyzes, records, and manages users' information of their health condition. We believe that this conceptual design of a mobile healthcare device can provide a new direction to the healthcare industry.

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## 2. LITERATURE REVIEW

A good product design has to meet customers' requirements and provide suitable product's functions with cost considerations. QFD is a method to translate customers' requirements into a product specification (Hauser and Clausing, 1988). Because there are many factors and their priorities to be determined, and even contradictions among them, other techniques such as ANP and TRIZ play supporting roles in the process to eliminate difficulties and gain benefits (Carnevalli and Miguel, 2008). To direct the new product development, we review related works in regards to four areas: (i) QFD, (ii) integration of QFD and TRIZ, (iii) integration of QFD and ANP, and (iv) QFD in healthcare.

### 2.1. QFD

QFD is a general concept that provides a method of translating customers' requirements into suitable technical requirements for each stage of product development and production (Sullivan, 1986). It achieves these goals by using the house of quality (HOQ), which is presented by a matrix describing the relationship between customers' requirements and product functions or characteristics (Hauser and Clausing, 1988). A typical HOQ consists of several elements to make the translation. In addition, QFD on the whole involves a sequence of "houses" from design characteristics, specific components, and production process to a quality plan (Stevenson, 2009). However, the number of needed "houses" depends on the target and its complexity in the problem solving. For instance, Chan and Wu (1998) organized four stages: translate the requirements into technical measures, the technical measures into parts characteristics, the parts characteristics into process operations, and the process operations into day-to-day production requirements.

QFD was derived from the quality requirements of Japan's manufacturing industry in the late 1960s and has been used worldwide in many industries and businesses. Due to the complexity of deployment, various quantitative methods have been suggested to improve the reliability and objectiveness of QFD (Chan and Wu, 2002). One well-known method is the analytic hierarchy process (AHP) to prioritize customers' requirements. According to the review by Ho (2008), 16 papers combine QFD and AHP, applying the integration to different areas. However, the limitation is the independence among customers' requirements, leading ANP to become an appropriate method instead.

### 2.2. Integration of QFD and ANP

ANP is a generalization of AHP dealing with dependence and feedback in the entire decision structure (Saaty, 2004). There are various ways to support QFD. A straightforward way to use AHP/ANP is to determine the weights of customers' requirements or demanded quality and then put them into the QFD process. Karsak *et al.* (2002) proposed a model that adds ANP for the inherent dependence in the QFD process. Partovi and Corredoira (2002) used ANP to determine the intensity of synergy effects among column variables of two sequential HOQs for the benefit of the sport of soccer. Partovi (2006 and 2007) considered ANP as having the same role for facility location selection and process selection, respectively, in three HOQs. Raharjo *et al.* (2008) argued that previous works using ANP are limited and proposed a general network framework for ANP with five clusters: goal, demanded quality, quality characteristic, new product design risk, and competitors. Lee *et al.* (2008) suggested an ANP-based multi-criteria decision making model in which a four-dimension HOQ makes three translations. Here, HOQ helps the decision-making process go more smoothly. Geng *et al.* (2010) presented an ANP network with three clusters to determine the initial important weights for HOQ. Büyüközkan and Berkol (2011) employed ANP to determine the importance levels in the HOQ. Some other techniques, e.g., goal programming, are also embedded for a special purpose in the integrated process.

### 2.3. Integration of QFD and TRIZ

TRIZ is a systematic approach for analyzing the kinds of challenging problems where inventiveness is needed (Altshuller, 1984), and it has been applied to various areas, especially for the effective development of new technical systems (Ilevbare *et al.*, 2013). Yamashina *et al.* (2002) argued that previous works could not effectively integrate QFD and TRIZ and proposed the innovative product development process in which QFD is used for obtaining customers' requirements. Wang *et al.* (2005) pointed out the same weakness of previous studies, integrated TRIZ by QFD for obtaining customers' inputs, and realized both methods on a set of software. Recently, the combinations of QFD and TRIZ have been targeted at some real-world applications, e.g., the re-use of consumer packaged goods (Vezzetti *et al.*, 2011) and the design of a customized tracheal stent (Melgoza *et al.*, 2012). Here, TRIZ is the core of the product/service development, while QFD is for setting up customers' requirements. On the contrary, Yeh *et al.* (2011) proposed a four-phase QFD for the design of a notebook PC in which TRIZ is exploited to solve the problem in each phase. The QFD study is the main framework of the development.

### 2.4. QFD in healthcare

In the area of healthcare, only a few works use QFD. Radharamanan and Godoy (1996) employed QFD for continuous improvement of quality in service for a healthcare system. Hallberg *et al.* (1999) introduced a customized QFD for designing a computer network service for occupational therapists. Moores (2006) exploited QFD for investigating radiation safety management in healthcare. Kuo *et al.* (2011) used Kano's model and the ANP theory to modify QFD for improving outpatient services for elderly patients in Taiwan. Most works here argue that quality is improved by taking into account customers' needs.

Although there are various applications of QFD, the integrations of ANP and TRIZ appear less in the literature. Hence, we propose a three-stage (or -phase) QFD model with ANP and TRIZ towards a conceptual design of a future mobile healthcare device for a better coherence.

## 3. THE PROPOSED MODEL

After exploring the characteristics of the ANP and TRIZ for supporting the process of translation in QFD, we propose a three-stage HOQ that collects the variable considerations, including customers' requirements as well as the product's functions, components, and costs for the conceptual design process. Figure 1 shows the framework.

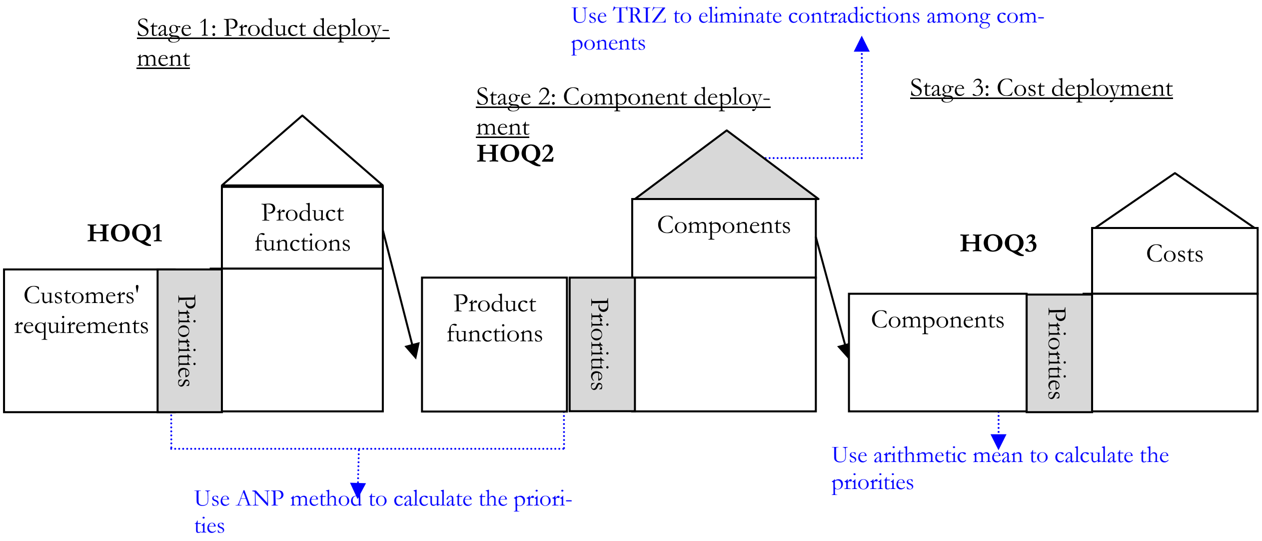

Figure 1. The proposed three-stage QFD

We can see that in the first two houses, ANP obtains the priorities of the left-side items with possible dependence and feedback. To let the whole conceptual design become more complete and innovative, TRIZ is considered to eliminate the contradictions at the roof of the second-stage HOQ so as to find a better solution to the mobile healthcare device.

Since there is no need for ANP and TRIZ supporting each HOQ, we simply divide the suggested procedure into the following six steps.

Step 1: Identify the items of three HOQs
Step 2: Calculate the priorities of the left-side items (the weights of WHATs)
Step 3: Acquire the what-how relationship
Step 4: Obtain the important ratings of the column items (the total scores of HOWs)
Step 5: Eliminate the contradiction of the components
Step 6: Recognize the main developments

### 3.1. Identify the items of three HOQs

We execute questionnaires, in-depth interviews, and scenario analysis to obtain data on customers' requirements, product functions, component items, and their costs. The data are then supplied to each HOQ. The first-stage HOQ (HOQ1) is for product deployment. We assign a list of the customers' requirements to the left side of the first house and put the items of product functions at the top side of the house. We then transfer the items of the product functions into the left side of the second-stage HOQ (HOQ2), i.e., component deployment, and allocate the items of the component to the top side of the second-stage HOQ. In a similar way, we relocate the items of the components to the left side of the third-stage HOQ (HOQ3), i.e., cost deployment, and set the items of the costs to the top of the house.

### 3.2. Calculate the priorities of the left-side items

We utilize two methods to calculate the priorities of the different structures of HOQ. For HOQ1 and HOQ2, there are possibly feedback and dependence among items, and so we use ANP to obtain the priorities of the left-side items. However, it is obvious that the costs are associated with the components in HOQ3. Hence, we take the arithmetic mean of the responses from experts to obtain the priorities of HOQ3's left-side items.

#### 3.2.1. Procedure of ANP

For HOQ1 and HOQ2, we select ANP to compute the priorities of their left-side items. The process can be divided into three phases.

Phase 1: Establish the network structures

In HOQ1 the goal of the ANP structure is customers' requirements, and the criteria that influence the goal are HOQ1's left-side items. In the same way, the goal is the product functions, and the criteria that influence the goal are the left-side items of HOQ2. By using questionnaires, we can ensure the relations of both networks, including dependence.

Figure 2 illustrates the network structure of the left-side items for HOQ1. A single arrow indicates a one-way relationship. For example, the arrow that leaves from demand 2 and feeds into demand 3 implies that demand 2 has an influence on demand 3.

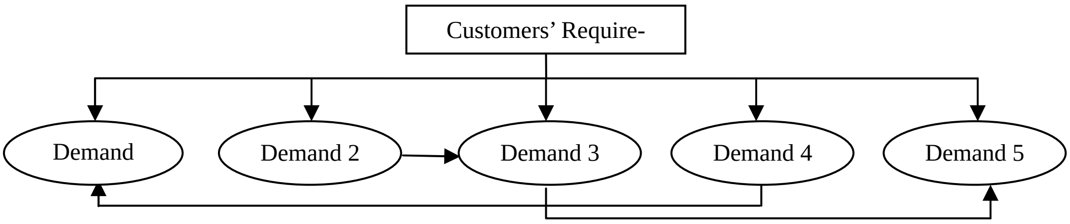

Figure 2. The network structure for the left-side items of HOQ1

Phase 2: Make pair-wise comparisons

We ask selected experts to pair-wise compare all items' criteria. The experts have to consider questions, including "Which criteria should be emphasized more?" and "How much more?" The responses are represented in numbers, which are based on Saaty's 1-9 fundamental scale (Saaty, 1980). We also execute similar questions about the relations of the interdependence among the criteria, if there are any. The experts have to answer some questions such as "Which criteria will influence C1 more: C2 or C3?" and "How much more?" (Saaty, 2004). Hence, various pair-wise comparison matrices are constructed for the criteria with interactions. All comparisons will be examined by the consistency ratio to confirm their consistency.

Phase 3: Establish a supermatrix and calculate the limiting priorities

After arranging the local priority vectors of the pair-wise comparison matrices, we obtain an unweighted supermatrix. We then weight the blocks of the supermatrix by the corresponding priorities to a weighted supermatrix, whose columns are stochastic, i.e., the sum of all column elements is 1. We multiply the supermatrix by itself until the priorities of each column are stable and limiting priorities are obtained.

#### 3.2.2. Procedure of arithmetic mean

Three experts are chosen to evaluate the importance of components and to fill in the questionnaire, which is measured by the 5-point Likert scale. After getting the importance of the components, we apply the arithmetic mean to aggregate the priority of each component.

### 3.3. Acquiring what-how relationship

The experts fill in the values of importance in the HOQ what-how relationship matrices. Traditionally, the relationship between the top-side items and left-side items is described as strong, medium, weak, and no relationship by the value of 9, 3, 1, or 0, respectively (Stevenson, 2009).

### 3.4. Obtain the important ratings of the column items (the total scores of HOWs)

The main output of the HOQ process is the important rating of the HOWs. As a result, we have to consider the priorities of the left-side items and the relation matrix of HOQ simultaneously. In order to calculate the important ratings of the HOWs, we generally take a simple additive weighting formula (Stevenson, 2009):

Important ratings of HOWs
$= \sum$ (the priorities of WHATs × relationship of the value between WHATs and HOWs) (1)

### 3.5. Eliminate the contradictions of the components

At the top of HOQ2, there is a relation grid on the roof with two types of symbols in the cell. The symbol "+" indicates there is a positive relation between two items, meaning that if a researcher emphasizes on devising one of them, then it will increase the benefit of the other item. However, "–" shows a negative relation between two items, i.e., if a researcher improves one of them, then it will deteriorate the other. In other words, negative relations imply bottlenecks or contradictions of items and restrict a deployment of the translation.

After confirming the items at the roof of HOQ2 with contradictions from these negative relations, we use TRIZ to transfer these contradictions into the appropriate parameters among the 39 Engineering Parameters (Altshuller, 1984). We then divide these parameters into "improving factors" and "worsening factors". The original problem is then transformed into the generic problem and follows the form of TRIZ's solution process. We next check the 39×39 Contradiction Table to find the principle numbers. According to the definition of 40 Inventive Principles, we can identify some possible developments and ideals. Please check Figure 3 for the process described.

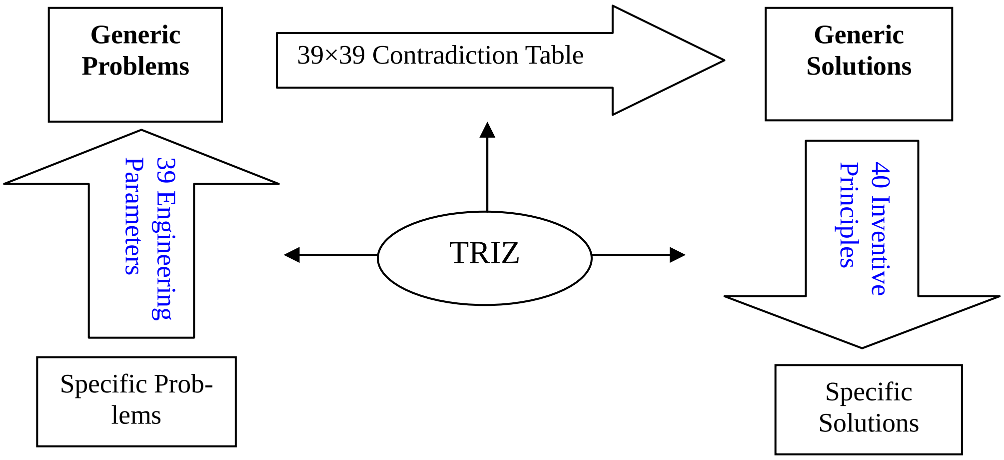

Figure 3. The TRIZ process for generating ideas

### 3.6. Recognize the main developments

In the final stage, we consider both the important ratings of HOQs and also the possible ideas from TRIZ. The output information from QFD suggests the high priorities for development.

## 4. CASE STUDY

We illustrate the case of conceptual design for a mobile healthcare device as follows.

Step 1: Identify the items of three HOQs

The abundant amount of information through questionnaires, in-depth interviews, and scenario analysis helps construct the three-stage QFD. HOQ1, HOQ2, and HOQ3 present the deployment of product, components, and cost, respectively.

Step 2: Calculate the priorities of the left-side items

After ensuring all the items of the three houses, we calculate the priorities of their left-side items. We use ANP for the items in HOQ1 and HOQ2 and arithmetic mean for the items in HOQ3. There are 11 items of customers' requirements and 13 items of product functions at the left sides of HOQ1 and HOQ2, respectively. Both are through the ANP networks by the help of experts to acquire the priorities of these items.

As mentioned in Phase 2 of Section 3.2.1, we then ask three experts to make comparisons among criteria and check their consistency. Tables 1 and 2 respectively show the left-side items of the unweighted supermatrices of HOQ1 and HOQ2. We then compute their weighted supermatrices and the limiting supermatrices. Table 3 lists the items of the numbers designated and the limiting priorities of the left-side items of HOQ1 and HOQ2.

Steps 3 & 4: Acquire the what-how relationship and obtain the important ratings of HOWs by Equation (1).

Tables 4, 5 and 6 show the relationship matrix of what-how in HOQ1, HOQ2 and HOQ3, respectively.

Table 1. The unweighted supermatrix of the left-side items of HOQ1

| | Customers' Requirements | 1-1 | 1-2 | 1-3 | 1-4 | 1-5 | 1-6 | 1-7 | 1-8 | 1-9 | 1-10 | 1-11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Customers' Requirements | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-1 | 0.04009 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-2 | 0.02075 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-3 | 0.10643 | 0.0987 | 0.1200 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-4 | 0.16711 | 0.30808 | 0.39385 | 0.27615 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-5 | 0.11493 | 0.18146 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-6 | 0.0669 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-7 | 0.0283 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-8 | 0.05272 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-9 | 0.29803 | 0.41176 | 0.48614 | 0.72385 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-10 | 0.05126 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1-11 | 0.05347 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

Table 2. The unweighted supermatrix of the left-side items of HOQ2

| | Product Func-tions | 2-1 | 2-2 | 2-3 | 2-4 | 2-5 | 2-6 | 2-7 | 2-8 | 2-9 | 2-10 | 2-11 | 2-12 | 2-13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Product Func-tions | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-1 | 0.01433 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-2 | 0.11509 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-3 | 0.06232 | 0.83333 | 0.06448 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-4 | 0.01892 | 0.16667 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-5 | 0.01653 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-6 | 0.10414 | 0.0000 | 0.24903 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-7 | 0.03342 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-8 | 0.04409 | 0.0000 | 0.07315 | 0.0000 | 0.0000 | 0.0000 | 0.08 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-9 | 0.18264 | 0.0000 | 0.27255 | 0.0000 | 0.0000 | 0.0000 | 0.44 | 0.0000 | 0.33333 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-10 | 0.0882 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.83333 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-11 | 0.1791 | 0.0000 | 0.17285 | 0.0000 | 0.0000 | 0.0000 | 0.26 | 0.0000 | 0.5 | 0.5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-12 | 0.01768 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2-13 | 0.12355 | 0.0000 | 0.16792 | 0.0000 | 0.0000 | 0.0000 | 0.22 | 0.16667 | 0.16667 | 0.5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

Table 3. The priorities of the left-side items of HOQ1 and HOQ2

| | **Left-side items of HOQ1** | **Priority** | | **Left-side items of HOQ2** | **Priority** |
|---|---|---|---|---|---|
| 1-1 | Software functions | 0.04009 | 2-1 | Diet control | 0.01433 |
| 1-2 | Hardware functions | 0.02075 | 2-2 | Dose interval remind | 0.11509 |
| 1-3 | User-friendly | 0.10643 | 2-3 | Exercise condition recorder | 0.06232 |
| 1-4 | Efficiency | 0.16711 | 2-4 | Quality of sleep check | 0.01892 |
| 1-5 | Privacy | 0.11493 | 2-5 | Regularly physical examination | 0.01653 |
| 1-6 | Customization | 0.0669 | 2-6 | OPD reservation | 0.10414 |
| 1-7 | Appearance | 0.0283 | 2-7 | GPS for medical facilities | 0.03342 |
| 1-8 | Portability | 0.05272 | 2-8 | IC card | 0.04409 |
| 1-9 | Accuracy | 0.29803 | 2-9 | Align to hospital | 0.18264 |
| 1-10 | Reasonable price | 0.05126 | 2-10 | Emergency support system | 0.0882 |
| 1-11 | After-sales service | 0.05347 | 2-11 | Privacy authorization function | 0.1791 |
| | | | 2-12 | Disassemble small detection device | 0.01768 |
| | | | 2-13 | Telemedicine service | 0.12355 |

Table 4. Relation information of HOQ1

| Customers' Requirements \ Product Functions | | Diet control | Dose interval remind | Exercise condition recorder | Quality of sleep check | Regularly physical examination | OPD reservation | GPS for medical facilities | IC card | Align to hospital | Emergency support system | Privacy authorization function | Disassemble small detection device | Telemedicine service |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Software functions | 0.0401 | □ | □ | □ | ○ | ○ | | □ | | ○ | ○ | ○ | ○ | ○ |
| Hardware functions | 0.0208 | △ | | □ | □ | | ○ | □ | | □ | ○ | □ | | ○ |
| User-friendly | 0.1064 | □ | □ | □ | □ | | | | □ | ○ | ○ | □ | | |
| Efficiency | 0.1671 | | | □ | | | □ | □ | | □ | □ | □ | | |
| Privacy | 0.1149 | □ | ○ | | △ | □ | ○ | | ○ | ○ | □ | ○ | | |
| Customization | 0.067 | ○ | □ | | □ | ○ | □ | □ | | ○ | ○ | ○ | ○ | ○ |
| Appearance | 0.028 | | △ | | △ | | △ | | △ | | □ | | △ | |
| Portability | 0.0527 | □ | | ○ | △ | | □ | □ | ○ | | ○ | | □ | □ |
| Accuracy | 0.2980 | ○ | ○ | ○ | ○ | □ | | ○ | | ○ | ○ | ○ | □ | |
| Reasonable price | 0.0513 | | | | | □ | △ | △ | △ | □ | | □ | □ | △ |
| After-sales service | 0.0535 | △ | △ | □ | □ | △ | | □ | △ | □ | | □ | | ○ |
| Importance | | 3.7826 | 3.9187 | 4.32 | 3.9817 | 2.409 | 2.1609 | 3.8164 | 1.9612 | 4.3774 | 6.195 | 4.893 | 2.1972 | 1.8403 |

Table 5. Relationship information of HOQ2

| Components / Product Functions | | Micro-Electro-Mechanical Systems | Wireless sensor network | USB 3.0 | Bluetooth 4.0 | Global positioning system | Professional medical support system | Cloud computing | Central processing unit | Open Services Gateway Initiative | Infrared thermal imaging temperature measure | Picture archiving and communication system | Quick Response Code | Wireless charging technology | Iris recognition system | Design of size and weight | Design of material and style |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diet control | 0.0143 | □ | □ | □ | △ | △ | ○ | | □ | | | | ○ | | | □ | |
| Dose interval remind | 0.1151 | △ | ○ | △ | □ | | | | ○ | | | | ○ | | | | |
| Exercise condition recorder | 0.0623 | ○ | ○ | △ | △ | | ○ | | ○ | | □ | □ | ○ | | | ○ | △ |
| Quality of sleep check | 0.0189 | ○ | ○ | △ | △ | | | | ○ | | □ | | ○ | | | | |
| Regularly physical examination | 0.0165 | △ | | △ | | △ | | | ○ | △ | | | ○ | | | | |
| OPD reservation | 0.1041 | | | | | | ○ | | ○ | | | □ | ○ | | | | |
| GPS for medical facilities | 0.0334 | ○ | | | ○ | ○ | | □ | ○ | □ | | | △ | | | | |
| IC card | 0.0441 | △ | □ | ○ | △ | | ○ | | ○ | | | | △ | | | ○ | ○ |
| Align to hospital | 0.1826 | △ | □ | △ | △ | | ○ | △ | ○ | △ | | □ | | | | | |
| Emergency support system | 0.0882 | ○ | ○ | △ | △ | ○ | | □ | ○ | △ | ○ | | □ | □ | □ | □ | △ |
| Privacy authorization function | 0.1791 | △ | △ | △ | △ | | ○ | | ○ | | | | | | ○ | | |
| Disassemble small detection device | 0.0177 | ○ | ○ | □ | ○ | | | | ○ | | □ | | | ○ | | ○ | ○ |
| Telemedicine service | 0.1236 | ○ | △ | △ | ○ | ○ | ○ | □ | ○ | | | □ | | | | | |
| Importance | | 3.6772 | 3.7456 | 1.2792 | 2.5067 | 2.2374 | 6.3916 | 0.9182 | 8.9140 | 0.3876 | 1.0906 | 1.4180 | 3.3240 | 0.4237 | 1.8766 | 1.4244 | 0.7064 |

Table 6. Relation information of HOQ3

| Costs | | Mechanical Cost | Design Cost | Test Cost | Material Cost | Project Management Cost |
|---|---|---|---|---|---|---|
| Micro-Electro-Mechanical Systems | 0.9375 | □ | ○ | ○ | | |
| Wireless sensor network | 0.625 | □ | | □ | ○ | □ |
| USB 3.0 | 0.625 | | □ | | ○ | |
| Bluetooth 4.0 | 0.6875 | | □ | ○ | | |
| Global positioning system | 0.6875 | | | | ○ | |
| Professional medical support system | 0.75 | □ | □ | ○ | | □ |
| Cloud computing | 0.5625 | □ | □ | ○ | | □ |
| Central processing unit | 0.625 | | | | ○ | |
| Open Services Gateway Initiative | 0.625 | □ | □ | □ | □ | □ |
| Infrared thermal imaging temperature measure | 0.5625 | □ | ○ | □ | | □ |
| Picture archiving and communication system | 0.625 | □ | ○ | □ | | □ |
| Quick Response Code | 0.6875 | | | ○ | □ | □ |
| Wireless charging technology | 0.5 | | ○ | | □ | |
| Iris recognition system | 0.5625 | | ○ | □ | | |
| Design of size and weight | 0.5 | | △ | △ | ○ | |
| Design of material and style | 0.5625 | | ○ | △ | | |
| Importance | | 14.0625 | 44 | 42.6875 | 33 | 13.3125 |

Step 5: Eliminate the contradiction of components

In this stage we emphasize the component items of HOQ2 only. The contradictions or negative relations are illustrated at the top of HOQ2 as in Figure 4 and Table 7 describes their effects on the design.

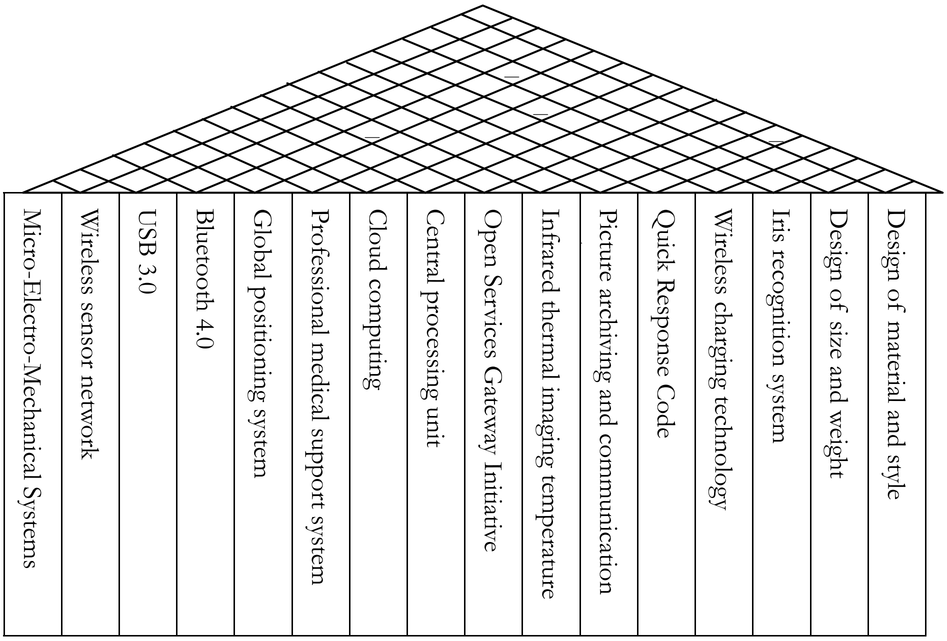

Figure 4. Negative relation among HOQ2 items

Table 7. Description of the contradictions

| **Contradiction** | | **Description** |
|---|---|---|
| Central processing unit | Wireless charging technology | If we want to improve CPU speed, it will increase the need for electricity. |
| Professional medical support system | Central processing unit | If the support system operates multi-processing, it will decrease CPU speed. |
| Wireless charging technology | Design of size and weight | If we need larger capacity to contain more electricity, then the need will result in heavier weight and larger volume of the device. |
| Professional medical support system | Wireless charging technology | If the support system operates multi-processing, it will increase the need for electricity. |

According to the TRIZ process of generating ideas, we transfer these components into the appropriate parameters and separate them into “improving parameter” and “worsening parameter” in order to check the 39×39 Contradiction Table and find the suitable Intensive Principles. The four contradictions found have gone through parameters and principles of TRIZ, and the used parameters and inventive principles are marked by the corresponding numbers in Table 8.

Table 8. Collation of the contradictions in TRIZ

| No. | Improving Parameters | Engineering Parameters | Inventive Principles | |
|---|---|---|---|---|
| | Worsening Parameters | | | |
| 1 | Central processing unit | 39. Productivity | 35. Parameter change | 10. Prior action |
| | Wireless charging technology | 19. Use energy by moving object | 38. Enrich | 19. Periodic action |
| 2 | Professional medical support system | 36. Device complexity | 12. Remove tension | 26. Copy |
| | Central processing unit | 39. Productivity | 17. Another dimension | |
| 3 | Wireless charging technology | 21. Power | 8. Counterweight | 38. Enrich |
| | Design of size and weight | 01. Weight of moving object | 36. Phase transition | 31. Hole |
| 4 | Professional medical support system | 36. Device complexity | 27. Cheap disposable | 2. Take out |
| | Wireless charging technology | 19. Use energy by moving object | 28. Mechanics substitution | 29. Fluid |

In the conceptual design stage we need the innovative idea so as to help designers find the creative points and think about the possibility for product development. Thus, we choose the appropriate principles and consider these principles in order to offer future development directions.

I. Central processing unit VS wireless charging technology
   - 10. Prior action: Solar power energy

   Using solar energy to store more power is the prior action to prevent it from being exhausted.

II. Professional medical support system VS central processing unit
   - 12. Remove tension: Multi-core CPU

   In order to use the device effectively, we use a multi-core CPU to deal with the multiple tasks.

III. Wireless charging technology VS design of size and weight
   - 31. Hole: Porous media

   Use porous media to reduce the weight of the electricity charging device.

IV. Professional medical support system VS wireless charging technology
   - 27. Cheap disposable: Disposable battery
   - 2. Take out: Disassemble battery

A new disassemble battery system is next designed so that users will be able to charge several batteries independently or to consider disposable batteries in order to maintain sufficient electricity power.

Step 6: Recognize the main developments

According to the importance of the three-stage HOQs and the TRIZ, we recognize the main developments and several creative ideas that indicate a future design direction. This information provides some major characteristics of the future device.

I. Top three important product functions: (i) Align to hospital, (ii) Emergency support system, and (iii) Privacy authorization function.
II. Top three essential components: (i) Central processing unit, (ii) Professional medical support system, and (iii) Wireless sensor network.
III. Top three major costs: (i) Test cost, (ii) Design cost, and (iii) Material cost.

To help readers catch the sense of the device, Figure 5 shows a draft of the future mobile healthcare device. On the front side, users have to verify their identification through iris recognition, and then they can start to use this device. On the back side, a blood glucose meter, blood pressure meter, and exercise condition detection are able to be dismantled according to the users' requirements. The functions of heartbeat detection and infrared thermal temperature measure detect the users' body condition. If the situation is abnormal, then the device gives a notice to its users. Moreover, if it is a serious condition, then the device provides a button for notifying a hospital and his/her emergency contact person.

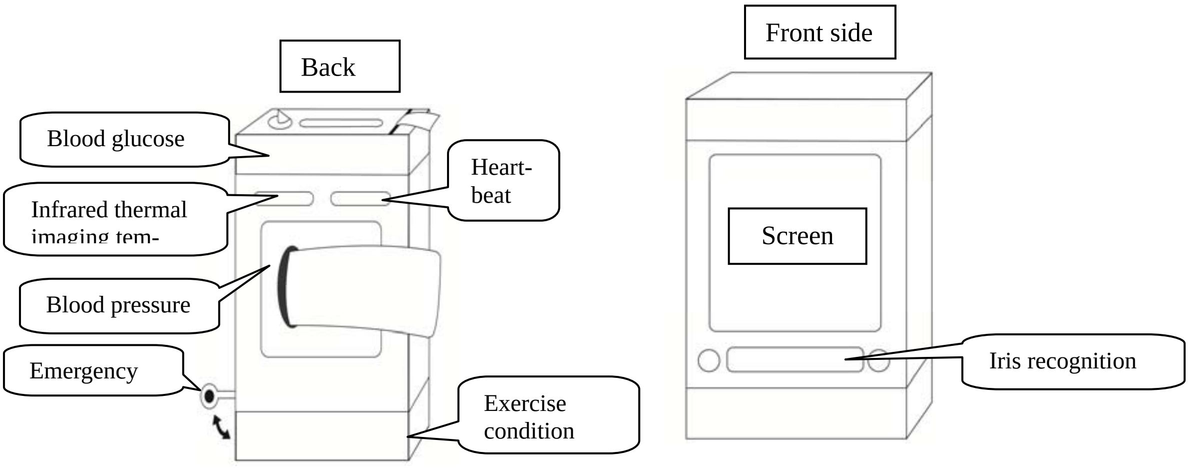

Figure 5. Draft of the mobile healthcare device

## 5. CONCLUSIONS

This research presents a model for a new product design by integrating a three-stage QFD with ANP and TRIZ, in which the model reduces the development time, ensures customers' requirements in the product specifications, and directs the resource allocation. The proposed process for designing a future mobile healthcare device points out some important features, meets the needs of customers, and could be a future direction for the development of the healthcare industry.

The analysis shows that the important functions of the mobile healthcare device are its align to hospital, an emergency support system, and a privacy authorization function. The essential technical specifications are central processing unit, professional medical support system, and wireless sensor network. The test cost, design cost, and material cost should be more emphasized in the cost aspect. There are also some creative ideas that provide directions for future development.

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