Design Studies and Intelligence Engineering
L.C. Jain et al. (Eds.)

doi:10.3233/FAIA250372

Research on Intelligent Mobile Nursing Cart Design Based on QFD

Zhengxin LUO[a], Qing WEN[a]and Fangyu LI[a1]
[a]*School of Design, Southwest Jiaotong University, Chengdu, Sichuan Province, 611756 , China*

Abstract. Starting from the needs of users, in order to solve the problems encountered by nursing staff when using nursing carts, combined with user experience map, QFD and Kano model, the users of mobile nursing carts are investigated, and the needs of users are obtained and transformed into needs. First, take hospital nurses as the research object, obtain user experience maps through observation and interviews, and use Kano questionnaires to classify user needs after preliminary extraction of user needs. Second, transform the acquired user needs into design elements and calculate their corresponding importance to establish a QFD model of mobile nursing carts. Finally, design practice based on design elements. The design of intelligent mobile nursing carts by transforming user needs into design elements aims to focus on the special group of nursing staff, provide them with more efficient nursing products, and provide a reference for the design of similar medical nursing tools.

Keywords. QFD; mobile nursing cart; nurse; user needs; user experience

1. Introduction

With the development of society, people's expectations and needs for medical services are gradually increasing. The nursing group plays a significant role in the medical service system. The "National Nursing Career Development Plan (2016-2020)" proposes to promote nursing informatization by leveraging information technologies, innovate and optimize nursing processes and service forms, and strengthen the nursing application information system to improve efficiency and reduce the workload of nurses[1]. The work of nurses is complicated and multitasking. The introduction of new technologies and reasonable work processes can enhance the quality of their work. Research shows that the time nurses spend on patients is directly proportional to the patients' recovery[2]. Therefore, improving the efficiency of nurses' non-clinical work can enable them to have more time to take care of patients. Paying attention to the work efficiency, movement trajectories, and work processes of nurses and solving the problems therein is the fundamental way to enhance the experience of medical services.

The mobile nursing cart, evolving from the traditional nursing treatment cart by adding a computer system, is an essential part of nursing work and an extension from the nurse station to the patient's bedside[3]. It improves nursing efficiency and patient experience by ensuring higher information processing efficiency, reducing nurses'

[1] Corresponding Author: Fangyu LI, School of Design, Southwest Jiaotong University, Chengdu, Sichuan Province, 611756 , China; E-mail: lfy2009@swjtu.edu.cn.

moving time and increasing bedside accompanying time. However, current hospital nursing cart designs mainly focus on product functions rather than user experience and needs. Quality function deployment (QFD), a user-centered research method, can transform user needs into various elements for higher customer satisfaction[4]. Liu Zongming and Ge Bihui, as well as Yang Danni and Wang Yi, have used QFD in elderly care designs[5] and car mounted fire extinguisher[6]. This article will build a needs model with QFD and conduct design practice based on relevant research results.

2. Construction of house of quality for intelligent mobile nursing carts and product design press

During the construction process of the House of Quality in QFD, combining the user journey map in service design and the Kano model can make up for the deficiencies of using QFD alone, obtain user needs more accurately, and make the obtained research results more authoritative and scientific[7]. The construction process of the House of Quality for the intelligent mobile nursing cart includes: drawing a user journey map through observation and interviews, collecting existing nursing cart products for analysis, obtaining preliminary needs from the user journey map, designing a user need questionnaire, calculating the importance and user satisfaction of preliminary needs, summarizing user need elements, determining the design elements of the intelligent nursing cart, calculating the importance of each design element, analyzing the design elements to construct a matrix and build the House of Quality, analyzing the correlation between design elements and needs, calculating the target values of each element, completing the construction of the House of Quality, and verifying whether each requirement is met.

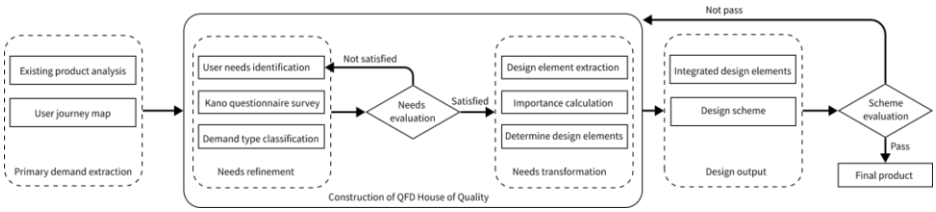

Figure 1. Quality house construction and design process.

According to the final calculation results of the House of Quality in QFD, integrate the design elements, present the design scheme, and obtain the final product through design evaluation.

3. Acquisition of needs for intelligent mobile nursing carts

The mobile nursing cart is crucial in the nursing system. Currently, it has three main types. The ABS mobile nursing cart is most popular due to rising medical service needs and nursing job needs. It's easy to move, clean, has good storage and can carry various products. But the non-computerized ABS cart makes nurses do many paper records,

adding to their workload. And compared to the computer-equipped one, it has drawbacks in size and weight despite some electronic office features.

Figure 2. Different types of nursing carts.

In Heji Hospital Affiliated to Changzhi Medical College in Shanxi Province, the work of gastrointestinal surgical nursing staff was recorded and interviewed. Their basic information table and the user journey map of using mobile nursing carts in nursing work were sorted out and drawn. From this, user characteristics and primary user needs were obtained. The primary needs include reducing the fear of patients during the education process, family members' cooperation in understanding doctor's orders and related matters, reasonable storage function of the nursing station, unobstructed movement, paperless and precise office work, efficient and easy to use system operation, reducing the tension brought by the nurse call bell, simpler cleaning work of tools and mobile nurse stations, and safer garbage disposal, etc.

Table 1. Basic characteristics of nurses.

Nurses	Position	Age	Gender	Educational Background	Length of Service	Height /CM	Satisfaction with Existing Mobile Nursing Products	Acceptance of Intelligent Mobile Nursing Products
A	Head nurse	32	female	Junior college	8.0 years	161.7	relatively high	relatively high
B	Nurse	24	female	Junior college	2.0 years	158.5	general	relatively high
C	Nurse	23	female	Junior college	1.5 years	159.6	general	relatively high
D	Nurse	27	female	Junior college	4.5 years	167.7	relatively low	relatively high
E	Nurse	23	female	Junior college	1.5 years	160.2	general	relatively high

4. Needs analysis of intelligent mobile nursing carts

4.1. Kano Questionnaire of Intelligent Mobile Nursing Cart

Through the analysis of existing mobile nursing cart products and the extraction of primary needs from the user journey map of the nursing cart, a Kano questionnaire is designed to study the actual user experience, further obtaining more accurate user needs. The fuzzy Kano questionnaire is shown in Table 2.

Table 2. Fuzzy Kano questionnaire.

Items	Number	Need Elements	Element Selection	Like	As It should be	Doesn't Matter	Can Tolerate	Dislike
Function	A1	Reasonable storage	Equipped	0.57	0.40	0.03	0.00	0.00
			Not equipped	0.00	0.00	0.32	0.33	0.35
	A2	Intelligent disinfection	Equipped	0.58	0.39	0.03	0.00	0.00
			Not equipped	0.00	0.00	0.29	0.38	0.33
	A3	Intelligent office	Equipped	0.60	0.34	0.06	0.00	0.00
			Not equipped	0.00	0.00	0.32	0.31	0.37
	A4	Quiet design	Equipped	0.62	0.37	0.07	0.00	0.00
			Not equipped	0.00	0.00	0.27	0.43	0.30
	A5	Safe garbage disposal	Equipped	0.37	0.60	0.03	0.00	0.00
			Not equipped	0.00	0.00	0.28	0.34	0.38
Interaction	A6	Intelligent reminder	Equipped	0.56	0.42	0.02	0.00	0.00
			Not equipped	0.00	0.00	0.40	0.31	0.29
	A7	Simple interaction	Equipped	0.56	0.43	0.01	0.00	0.00
			Not equipped	0.00	0.00	0.30	0.36	0.33
	A8	Intelligent teaching	Equipped	0.62	0.31	0.07	0.00	0.00
			Not equipped	0.00	0.00	0.32	0.38	0.30
Modeling	A9	Simple modeling	Equipped	0.69	0.28	0.03	0.00	0.00
			Not equipped	0.00	0.00	0.29	0.43	0.28
	A10	Light weight	Equipped	0.62	0.34	0.04	0.00	0.00
			Not equipped	0.00	0.00	0.25	0.28	0.47

4.2. Classification of needs for Intelligent Mobile Nursing Carts

Mining the types of user needs and analyzing the importance of user needs are the keys to innovative product design[8]. The types of user needs are specified as five, namely basic needs, expected needs, attractive needs, indifferent needs, and reverse needs, as shown in Table 3.

Table 3. User needs type.

Needs Types	User Satisfaction	
	When the Attribute is not Present	When the Attribute is Present
Basic needs (M)	Decrease	Unchanged
Expected needs (O)	Decrease	Increase
Attractive needs (A)	Unchanged	Increase
Indifferent needs (I)	Unchanged	Increase
Reverse needs (R)	Unchanged	Decrease

The needs data obtained from the Kano questionnaire is analyzed and evaluated according to Table 4, and then the needs types are determined one by one according to Table 3. A total of 170 questionnaires were distributed in this user needs survey, and 136 valid questionnaires were recovered, with a recovery rate of 80%. The respondents are all in service nursing staff from Heji Hospital Affiliated to Changzhi Medical

College in Shanxi Province, Changzhi People's Hospital, and People's Hospital of Pidu District, Chengdu City, Sichuan Province. The questionnaire data are credible. Through calculation, various needs elements are classified. Take A2 as an example. When the A2 feature is present, 57% of users choose "like", and when the A2 feature is absent, 35% of users choose "dislike". Therefore, corresponding to Table 4, the user needs of A2 belong to the expected needs in Table 3. Similarly, A6 belong to the attractive needs.

Table 4. User needs element classification.

Elements without the Design Elements						
Elements with the Design Elements	**Types**	**Like**	**As It Should Be**	**Doesn't Matter**	**Can Tolerate**	**Dislike**
	Like	Q	A	A	A	O
	As it Should Be	R	I	I	I	M
	Doesn't Matter	R	I	I	I	M
	Can Tolerate	R	I	I	I	M
	Dislike	R	R	R	R	Q

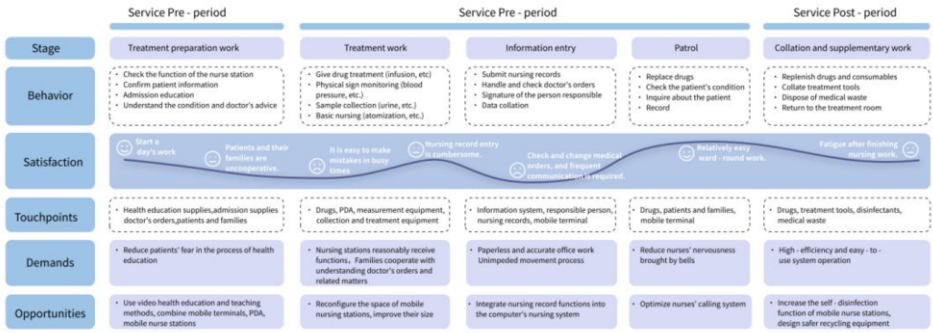

Figure 3. User journey map of mobile nursing carts.

5. Transformation of user needs based on QFD

5.1. Importance of user needs for intelligent mobile nursing carts

Before product design and development, it is crucial to determine the importance of user needs. The ranking of need importance directly affects the direction and focus of product design and development. User satisfaction and importance are the key inputs of the improved House of Quality matrix.

According to the importance evaluated by Kano, the value range is specified as 0-5, corresponding to the five types in the need types. The higher the importance value, the higher the value of its corresponding need in product design. The need types and importance of the intelligent mobile nursing cart are shown in Table 5.

Table 5. Types of needs and importance of needs of nursing cart users.

Items	Number	Need Elements	Needs Types	Importance	Measures
Function	A1	Reasonable storage	Expected needs	4	Retain
	A2	Intelligent disinfection	Attractive needs	3	Retain
	A3	Intelligent office	Expected needs	4	Retain
	A4	Quiet design	Attractive needs	3	Retain
	A5	Safe garbage disposal	Basic needs	5	Retain

Items	Number	Need Elements	Needs Types	Importance	Measures
Interaction	A6	Intelligent reminder	Attractive needs	3	Retain
	A7	Simple interaction	Attractive needs	3	Retain
	A8	Intelligent teaching	Attractive needs	3	Retain
Modeling	A9	Simple modeling	Attractive needs	3	Retain
	A10	Light weight	Expected needs	4	Retain

5.2. Construct the house of quality for intelligent nursing carts

By calculating the relative weights of user needs quality of the mobile nursing cart, the House of Quality of the mobile nursing cart is constructed, thereby determining the design elements of the product. First, construct user needs matrix of the House of Quality of the mobile nursing cart. User needs include simple shape, light weight, reasonable storage, utensil disinfection, etc. Then calculate the relative weight of the need quality. Then calculate the relative weight of the needs quality. The relationship between the horizontal improvement rate and product characteristics can be expressed by Equation (1).

$$\omega = I \times R \times C \tag{1}$$

In the formula: ω - the absolute weight of the needs quality; I - importance evaluation; C - product characteristic.Then calculate the relative weight $\omega_i^{'}$ of the needs quality weight according to Equation (2):

$$\omega_i^{'} = \frac{\omega_i^{'}}{\sum_{i=1}^{n} \omega_i^{'}} \tag{2}$$

Calculate the weight ω_j of the quality element as obtained according to Equation (3):

$$\omega_j^{'} = \sum_{i=1}^{n} \omega_i^{'} R_{ij} \tag{3}$$

Finally, calculate the relative weight (4) from the result of ω_j:

$$\omega_j^{'} = \frac{\omega_j}{\sum_{i=1}^{n} \omega_j} \tag{4}$$

Fill the calculation results into the House of Quality of the mobile nursing cart, and establish the House of Quality of the design quality elements of the mobile nursing cart and the customer needs quality composed of key quality elements in three aspects of shape, function, and interaction, as shown in Table 6 and Table 7.

Table 6. Design Quality Elements of Mobile Nursing Cart.

User Needs	Quality Elements							
	Appearance Modeling	Material Weight	Space Utilization	Safety and Hygiene	Intelligence	Ease of Use	Comfort	Efficiency
Simple modeling	5	5	4	0	0	4	3	0
Light weight	3	5	3	0	0	3	4	3
Reasonable storage	3	0	5	0	0	5	4	5
Intelligent disinfection	0	0	3	5	3	4	0	0
Intelligent office	0	0	0	0	5	5	4	5
Quiet design	0	5	0	0	0	0	3	0
Safe garbage disposal	0	0	3	5	0	4	0	3
Intelligent reminder	0	0	0	0	5	5	3	0
Single operation	3	0	4	0	4	5	0	5
Efficient education	0	0	0	0	3	0	0	4
Weight of quality elements	146.9	128.5	230.7	84.5	207.8	384.7	218.4	295.5
Relative weight	8.7%	7.6%	13.6%	5%	12.2%	55.2%	12.9%	17.4%

Table 7. Customer Needs Quality House.

User Needs	Importance Evaluation	The Current Level	Quality of Plan				Needs Quality Weight
			Plan Quality Level	Needs Increase Rate	Product Features	Absolute Weight	
Simple modeling	3	3	4	1.33	1.2	4.78	7.0%
Light weight	4	3	5	1.66	1.2	7.96	11.7%
Reasonable storage	4	3	5	1.66	1.5	9.96	14.6%
Intelligent disinfection	3	3	4	1.33	1.0	3.99	5.9%
Intelligent office	4	3	5	1.66	1.5	9.96	14.6%
Quiet design	3	3	4	1.33	1.2	4.78	7.0%
Safe garbage disposal	5	4	5	1.25	1.2	7.5	11.0%
Intelligent reminder	3	2	4	2	1.2	7.2	10.6%
Single operation	3	3	5	1.66	1.5	7.47	11.0%
Efficient education	3	2	3	1.5	1.0	4.5	6.7%

6. Design practice of intelligent mobile nursing carts

Combined with the user journey map, Kano questionnaire and the calculation results of the QFD House of Quality, the final design elements of the intelligent nursing cart are obtained. It can be known from the relative weights in Table 6 that during the design of the nursing cart, the most important aspects to focus on are its ease of use, high efficiency and comfort. Combined with the existing nursing carts, these design goals can be achieved through the distribution of functional space and the design of shape and size, thus improving user satisfaction. From the ranking of the importance of the functions of the nursing cart, space utilization and intelligence are the focuses of this design, with the relative weights accounting for 13.6% and 12.2% respectively. Therefore, in the design, reasonable arrangement of space should be considered according to the size, frequency of use and functional needs of the items needed by users. The intelligent design should be combined with some terminal devices in the current nursing system, such as tablets, personal digital assistants, mobile phones, etc, to meet the needs of users.

6.1. The shape design of intelligent mobile nursing carts

According to the extracted shape needs, the intelligent mobile nursing cart is designed and a sketch is drawn, as shown in Figure 6. Since the nursing cart is a medical product, the shape style should be simple and the color should be mainly light toned. The actual size of the nursing cart is designed with reference to the 50th percentile of data standards such as the daytime elbow height, hand function height, and forearm length of adult women in GB/T 12985-1991[9]. At the same time, a card slot for intelligent interactive equipment is added to the working surface of the ordinary nursing cart to avoid the heaviness of a desktop computer and also to complete paperless nursing tasks accordingly.

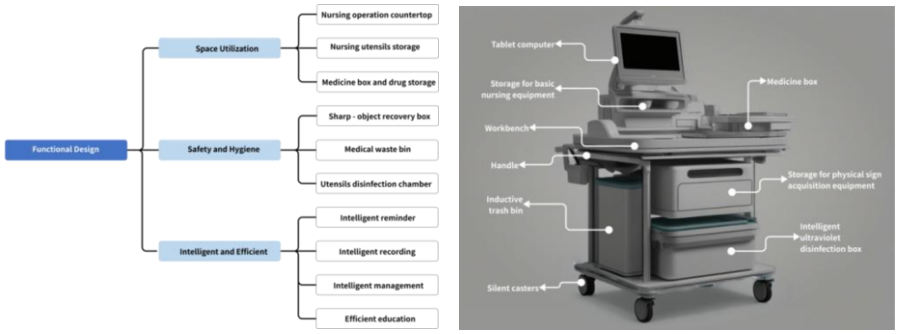

Figure 4. The necessary functional modules of the intelligent mobile nursing cart.

6.2. Functional design of intelligent mobile nursing carts

According to the calculation results of the House of Quality in QFD, the functional design elements of the intelligent mobile nursing cart are sorted out. As shown in Figure 5, the functions of the intelligent nursing cart can be designed from three aspects. In terms of space utilization, the cart should have a basic nursing operation table for various nursing operations; there should be a reasonable storage space for nursing tools

to improve the current deficiency in cart storage; there should be basic medicine boxes for storing corresponding medicines to improve the efficiency of nurses in drug administration. In terms of safety and hygiene, the nursing cart should have a basic sharp object recycling box and a dedicated medical waste bin to prevent harmful medical waste from causing unnecessary harm to the human body. The existing nursing carts already have this design element, and on this basis, an ultraviolet disinfection chamber can be added to disinfect the nursing tools used in daily life and maintain hygiene. From the aspect of intelligence and high efficiency, it is mainly reflected in the nursing system which is matched with the mobile nursing cart. With a tablet computer as the carrier, it contains functions such as intelligent reminder, intelligent record, intelligent management, and efficient education, saving the user's working time.

Figure 5. Intelligent nursing cart renderings.

6.3. Interactive design of intelligent mobile nursing carts

The intelligence of the intelligent mobile nursing cart is mainly reflected in the intelligent management system installed on the cart. Besides the system functions such as intelligent reminder, intelligent record, intelligent management, and efficient education, the ease of use and learnability of the entire system should be separately considered in the design. For example, in terms of system color matching, cool colors should be chosen as the main colors of the entire system, such as the blue and white color combination. High purity red, yellow, and orange have the characteristics of being passionate and lively, with strong visual effects[10], and are not suitable for large area use in the nursing system. However, these colors can be used as auxiliary colors for the equipment to emphasize or warn of some functions of the product, such as emergency prompts. The system interaction mode is mainly based on point or touch screen. Considering the complex environment of the ward and the nurse station, the voice interaction mode is not suitable for application in the nursing system.

Figure 6. Nursing system interactive interface.

7. Conclusion

The design process of medical intelligent products is rather complicated. Incorporating the user journey map of service design and the Kano model into the QFD design method can improve the accuracy of user needs transformation. Taking the design of an intelligent mobile nursing cart as an example, this paper conducts qualitative and quantitative data analysis on the collected user needs. Eventually, the needs are ranked in terms of importance and transformed into corresponding design elements to provide guidance for design practice. This design process can provide a reference for subsequent product research and development, making the product more in line with user needs and thus enhancing the user experience of such products.

Acknowledgement

The project is supported by the Ministry of Education's Industry-University-Research (Grant No.202101071008,202101332005,22077093280056). The First Batch of Provincial Research and Reform Practice Projects of New Liberal Arts in Sichuan Province (Multidisciplinary Integration of Interaction Design Curriculum and Teaching Material System in the Context of "New Liberal Arts + Intelligence").

References

[1] SHAO H,YANG A L ,PANG Q J. Application effect of mobile nursing rounds in wards [J]. *Modern Practical Medicine*,2017,29(04):556-557.
[2] DONG M,YANG W J. The combined application of mobile nursing cart and terminal control computer in bedside nursing [J]. *Chinese Journal of Nursing*,2013,48(05):471-472.
[3] CHEN W J . Application and development of mobile nurse workstation in clinical nursing work [J]. *Information System Engineering*,2016(11):108-109.
[4] LI Y L,TANG J F,YAO J M,PU Y,XU J. The Method of Determining the Importance of Customer Demand Improvement in the House of Quality [J]. *Journal of Mechanical Engineering*,2007(11):110-118.
[5] LIU Z M,GE B H. QFD-based design of home care robot for the elderly [J]. *Journal of Graphics*,2018,39(04):695-699.
[6] YANG D N,WANG Y. Research on Design of Vehicle Fire Extinguisher Based on KANO Model and QFD Demand Transformation [J]. *Technology and Innovation*,2020(11):3-7.
[7] SHI Y W,HAN S. Research on Modeling Design of Medical Service Robot Based on QFD and Kano Model [J]. *Mechanical Design*,2017,34(12):121-125.
[8] LIU H E,ZHANG L P. Summary of Research Progress on Quality Function Deployment (QFD) Theories and Methods [J]. *System Engineering*,2000(02):1-6.
[9] *General Principles for Applying Percentiles of Human Body Dimensions in Product Design* [S]. Institute of Psychology, Hangzhou University, 1991.
[10] ZHAO X G,SHEN T. Preliminary study on color design in medical space environment [J]. *Art and Design (Theory)*,2020,2(03):38-4.