Research on Innovation Design of Fire Truck Based on Evaluation Grid Method

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Abstract: Fire safety problems frequently appear in the city, in order to ensure the firefighters to quickly and effectively carry out fire fighting and rescue tasks, a fully functional and intelligent fire truck is urgently needed equipment. Starting from the objective needs of first-line firefighters, this paper aims to provide an accurate reference direction for the design of fire truck through scientific and effective research and design methods. Firstly, the fire fighters were interviewed and investigated by questionnaire with the method of evaluation grid method in miryoku engineering. Then, the quantification theory type I is used to analyze the questionnaire data. Finally, according to the analysis results and combined with the modular design concept for design innovation. The newly designed fire truck has been improved in the aspects of practicality and functionality, which improves the efficiency of urban rescue missions.

1. Introduction

China's population ranks first in the world, according to the data of the National Bureau of Statistics, the total population of China as of 2017 is 1.39008 billion, of which the proportion of urbanized population is about 58.53% [1]. With the rapid development of Chinese economy, residential areas, large commercial streets and office buildings in cities are becoming more and more dense, which leads to frequent fire safety problems in cities [2]. In addition, according to the statistics of China Emergency Management Fire and Rescue Bureau, a total of 237000 fires occurred throughout the country in 2018, and 2.193 million fire engines were dispatched, resulting in 14.07 deaths ,798 injuries, and direct property losses of 3.675 billion [3]. Therefore, China's fire work is facing a severe test, urgently need a batch of fully functional and intelligent fire equipment. Fire truck is responsible for guarding the city's fire safety, so a lot of research and development funds are invested in the design innovation of fire truck. Up to now, the United States, the United Kingdom, Germany, Japan, France and other countries that have paid attention to the research and development of fire trucks earlier have made some research achievements, such as the tracked TAF20 multi-function fire truck in the United States, the RO-VEH remote-controlled fire truck in the United Kingdom, the German LUF60 fire truck, and the small FLYGO fire truck in Japan. China has a late start in the research and development of fire trucks, and there are still some problems compared with developed countries, specifically reflected in the intelligence degree is not enough, reliability is not high, environmental identification ability is weak [4]. Therefore, China still has a lot of progress and development space on the design of fire engines, which requires a large number of of designers. Therefore, China still has great progress and development space in the design of fire truck, and it is necessary to call on the majority of design workers to carry out design innovation.

It is well known that scientific and rigorous research methods contribute to design innovation. Firefighters are the direct use group of fire fighting equipment, if we can accurately grasp the real needs of firefighters in the process of fire extinguishing through effective research methods, we can carry out accurate and innovative design. The evaluation grid method (EGM) can deeply explore the potential demand of users, and the quantification theory type Ⅰ can further clarify the charm factors of fire truck on the basis of EGM. On this basis, through the modular design concept to

selectively inherit charm factors, so as to improve the creativity of fire trucks, finally make up for the shortage of China's fire trucks. The purpose of this study is to improve the design of fire truck by objective and effective research methods. Section 2 describes in detail the research methods and theories involved in this paper. Section 3 describes the concrete implementation steps. Section 4 takes fire truck as the case study.

2. Theoretical Background

2.1 Evaluation Grid Method

Miryoku engineering belongs to kansei engineering, and evaluation construction method (EGM) is the primary research method under the category of miryoku engineering. At its root, EGM is developed on the basis of repertory grid method [5]. Specifically, the EGM is to excavate/capture the cognitive concept of people through in-depth interviews. The specific means is to compare the target object A and B, and then to ask for the similarity or difference between them. After integrating the answers of all the interviewees, the charm network diagram about the target product at three levels is constructed [6].

EGM is widely used in product design field. Zhang [7] systematically analyzed the application of EGM in product design and took the teapot as a case study. Lu and Pei [8] applied EGM to the improved design of range hoods to establish the correspondence between personal preference and specific characteristics. Yang [9] optimized the design of tea infuser through EGM. Xi et al. [10] optimized the design of the mini electric vehicle through EGM. Furthermore, many scholars apply EGM to other fields. From the perspective of aesthetics, Ho [11] extracts the charm factor of App Icons through EGM to help designers improve the overall visual effect. Han [12] applied EGM to analyze the charm factors of stationery stores and put forward some specific suggestions for the development of the industry. In addition, Han [13] analyzed the charm factors of online teaching through EGM, providing valuable suggestions for the development of education. It can be seen that EGM is an objective and effective research method, which can effectively improve the design. Therefore, this study will carry out design innovation of fire truck through EGM.

2.2 Quantification Theory Type Ⅰ (QTTⅠ)

Quantitative theory is a scientific statistical method for the study of qualitative data [14]. Among them, quantification theory type Ⅰ (QTTⅠ) uses multiple regression analysis to establish the mapping relationship between independent variable x and dependent variable y, so as to realize the prediction of dependent variable y [15]. In many studies on miryoku engineering, scholars often combine QTTⅠ with EGM to construct the correlation between charm factors and various projects, and then judge the credibility of the results based on the determination coefficient. Therefore, this paper still combines the EGM with QTTⅠ to achieve the analysis and extraction of charm factors, which a reference for the innovative design of target products.

2.3 Modular Design Concept

The concept of modular design is to disassemble and redesign products according to their functions or performance, form a series of modules with specific functions, and then form products with new functions by means of replacement, upgrading, selection and reorganization, so as to meet the different needs of the market and the environment [16]. In the specific application process, first to determine the dependency between the modules, and then to optimize the design of each module, and finally to improve the overall design quality. The basic principle of modular design is 1) Modules should have high compatibility, that is, using a small number of modules to achieve as many functions as possible, and on this basis to improve the accuracy of the product, increase performance, save costs and simplify the structure; 2) Ensure that the modules are serialized, that is, the limited variety and specifications are used to meet the needs of users. The characteristics of modular design include relative independence interchangeability and versatility. Many scholars

combine the modular design concept to carry out design practice, such as combined furniture, bicycle, robot and so on [17], which proves that the modular design concept is a practical and effective design method. This paper also adopts this concept in the innovative design of fire truck.

3. Implementation Procedures

Based on the theory described in Section 2, this paper aims to propose an innovative design method for urban fire trucks. The specific implementation procedures are described as follows. Step 1: Identify target products; Step 2: Determine the interviewees; Step 3: Prepare interview materials; Step 4: Conduct in-depth interviews; Step 5: Obtain original evaluation items (middle layer); Step 6: Obtain abstract reason (upper layer) and concrete condition (lower layer) according to middle layer. Step 7: Obtain personal evaluation structure map; Step 8: Obtain the overall evaluation structure map; Step 9: Carry out questionnaire survey and analyze with QTTⅠ; Step 10: Get charm factors for reference; Step 11: Use modular design concept to innovate design.

4. Case Study

For the target product fire truck, this paper integrates EGM, QTTⅠ and modular design concept to carry on the innovation design, the detailed research process is described below.

4.1 Preparation of Interview Samples

As a stimulus, samples will directly affect the effect of the interview. In order to avoid the of the sample being unrepresentative, this study first collected a large number of sample materials from references and relevant professional websites, and then carefully selected 10 representative fire trucks after focus group discussion, and finally made them into cards of the same size. Each card shows the same fire truck from different angles, and is accompanied by a simple description, including the function of the fire truck, material, color, material and other basic information.

4.2 Determining the Interviewees and Conducting In-depth Interviews

In order to get accurate charm factors for design innovation, respondents must be familiar with fire truck. Therefore, the firemen of Xi'an Fire Center were selected as the interviewees for in-depth interviews. As the front-line soldiers at the scene of fire fighting, firefighters need to control the fire truck to carry out the rescue task every time they perform the task, so firefighters can be regarded as the professional users of the fire truck. Through the expert interview, the charm factors of the fire truck can be classified, screened and condensed. After further sorting, the indescribable charm factors can be concretized and clarified, which can be used as a reference for innovative design. A total of 10 firefighters were invited as interviewees. During the interview, the interviewees were asked to choose according to subjective preference in the disrupted cards, then to make a pairwise comparative analysis, and to describe the preferred trait by using "good or bad" or "likes and evils" as the standard, which is the original evaluation item (OEI). Then, continue to ask the abstract evaluation item (AEI) and concrete evaluation item (CEI) based on the OEI. After the interview, the information of each interviewee was sorted out in turn, and the personal evaluation structure map was finally sorted out.

4.3 Drawing the Evaluation Structure Map

This stage can be divided into two steps, one is to draw the personal evaluation structure map, and the other is to draw the overall evaluation construction map. A total of 8 upper, 15 median and 25 lower were obtained by preliminary statistics. Then, merge or delete the items with similar meanings in the preliminary statistics, and finally sort out the final map (3 upper, 8 median, and 21 lower) as shown in figure 1. This map can be regarded as a collection of charm factors of fire trucks, which has important guiding significance for the later innovative design. In order to further narrow the scope of

reference factors, it is necessary to conduct a questionnaire survey on more firefighters based on the structure map.

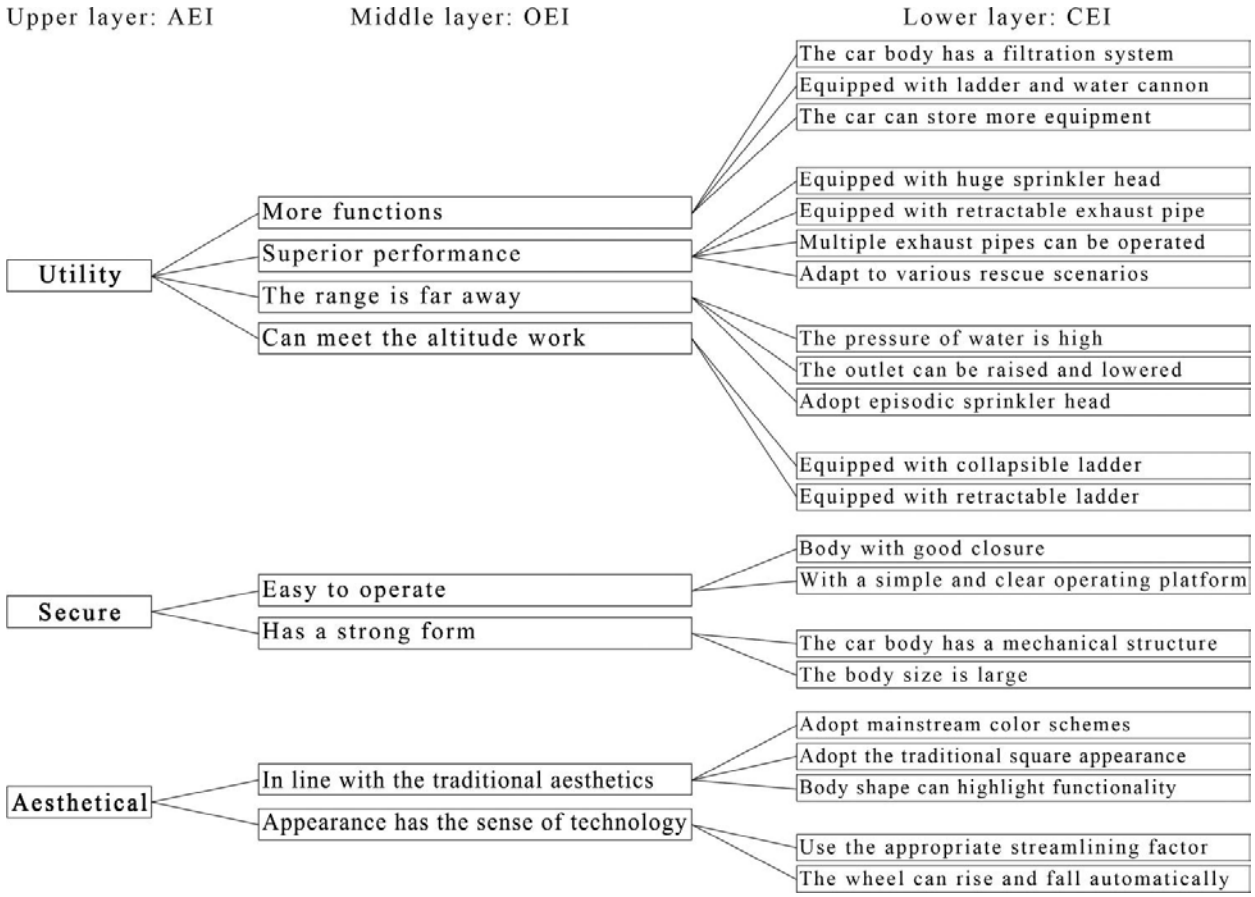

Figure 1. Two or more references

4.4 Questionnaire Survey and Analysis of QTT Ⅰ

In this stage, the questionnaire is made according to the evaluation structure map drawn and divided into 3 parts according to the AEI. Each part takes OEI as the question and CEI as the option. A total of 40 valid questionnaires were collected, and then the QTT Ⅰ was used to analyze the questionnaire data. In the process of analysis, the CEI (lower layer) was set as the independent variable x, and the sum of the importance degree of OEI (middle layer) was set as the dependent variable y. The correspondence between the two items was constructed through multiple regression analysis. The results are shown in table 1 to table 3. It can be seen that for "Utility" fire truck, the "Superior performance" is a crucial factor; For "Secure" fire truck, the "Has a strong form" is a crucial factor; For "Aesthetical" fire truck, the "Appearance has the sense of technology" is a crucial factor. Therefore, when designing innovation, these factors should be considered first. In addition, the CEI with highest category score can be used as a reference factor, specifically "Equipped with ladder and water cannon", "Multiple exhaust pipes can be opearted", "The outlet can be raised and lowered", "Equipped with retractable ladder", "Body with good closure", "The body size is large", "Body shape can highlight functionality", "Use the appropriate streamlining factor".

Table 1 Results of QTT Ⅰ on “Utility”

Original Item	Best Appeal Features	CS[a]	PCC[b]	Ranking
X1 More functions	Equipped with ladder and water cannon	0.3240	0.3192	3
X2 Superior performance	Multiple exhaust pipes can be operated	2.1102	0.4670	1
X3 The range is far away	The outlet can be raised and lowered	0.7843	0.4083	2
X4 Meet the altitude work	Equipped with retractable ladder	0.2819	0.2070	4

R	0.6045

Table 2 Results of QTTⅠ on “Secure”

Original Item	Best Appeal Features	CS[a]	PCC[b]	Ranking
X1 Easy to operate	Body shape can highlight functionality	0.2106	0.1271	2
X2 Has a strong form	Use the appropriate streamlining factor	0.7430	0.3779	1
	R		0.3852	

Table 3 Results of QTTⅠ on “Aesthetical”

Original Item	Best Appeal Features	CS[a]	PCC[b]	Ranking
X1 In line with the traditional aesthetics	Body with good closure	0.0687	0.3192	2
X2 Appearance has the sense of technology	The body size is large	0.0756	0.4670	1
	R		0.1030	

4.5 Combining Modular Design Concept to Innovate Design

On the basis of the preliminary analysis, this stage is guided by the modular design concept to ensure that the newly designed fire truck inherits the charm factor, and to improve the ability of the newly designed fire truck to adapt to various environments. The specific description is as follows. The car body is divided into 5 modules (figure 2(a)), including the main module 01, connection module X, the water tank module A, the smoke extraction module B and the ladder module C. If the overall expression of the fire truck is M, it can be expressed as M=01+X+A(or B, C). Among them, 01+X can be regarded as the basic module, and A, B and C as the supplementary functions. The basic module is morphologically different from the active fire truck, specifically expressed in the strong and solid contour curve but different from the active fire truck's rectangular contour, which conforms to "Body with good closure" and "Use the appropriate streamlining factor". In addition, the top water gun can adjust the injection angle, in line with the "The outlet can be raised and lowered"; The main function of water tank module A (figure 2(b)) is to supply water. The square space can store a large amount of water, which is in line with "The body size is large"; The smoke extraction module B (figure 2(c)) is equipped with 6 sets of cylindrical air outlets and 2 sets of cylindrical water mist spraying ports, and its bottom is equipped with hydraulic lifter, which can adapt to different environments and meet "Multiple exhaust pipes can be opearted"; The ladder module C (figure 2(d)) is composed of 4 parts, including hydraulic device d, support bar e, basket f and anti-aircraft gun g, to meet the rescue and fire fighting tasks in the high-altitude environment, in line with "Equipped with ladder and water cannon" and "Equipped with retractable ladder"; In addition, after the combination of different supplementary functional modules (A, B, C) and basic modules (01+X), the main functions can be visually distinguished from the morphology, which conforms to "Body shape can highlight functionality". In summary, the modular design concept can ensure that the new design of fire engines inherit the charm factor.

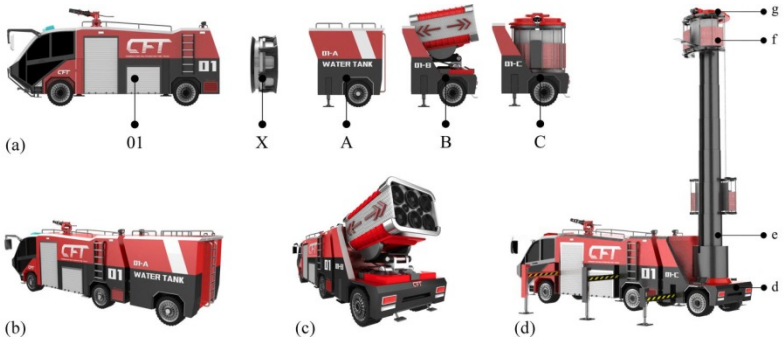

Figure 2. The newly designed fire truck
(a) All modules (b) Water tank module (c) Smoke extraction module (d) Ladder module.

5. Summary

This paper integrates the evaluation grid method (EGM), quantification theory type Ⅰ (QTTⅠ) and modular design concept in the innovative design of fire truck. The EGM can excavate the potential charm factors of fire truck, the QTTⅠ can further clarify which charm factors are crucial, and the modular design concept can carry out innovative design on the basis of inheriting charm factors. Through the in-depth interview of experts, the evaluation structure map can be obtained, in which the specific conditions provide a large number of specific reference factors, and provide a clear standard for design innovation. The newly designed fire truck has some improvement in "utility", "secure" and "aesthetical" which has certain guiding value to the development of fire truck. From the above, the innovative design method proposed in this paper is a scientific and effective approach, although the fire truck as a case study, but also applicable to other product design.

References

[1] Z. G. Guo, Accelerate the Establishment of the Long-term Goal of China's Population Development Strategy. Chinese Cadres Tribune. Vol. 14 (2020), No. 2, p. 50-55.

[2] Y. B. Chen, H. Zhang, D. J. Yu, Design of City Main Battle Fire Engine Based on the Integrated Innovation Theory. Packaging Engineering. Vol. 40 (2019) No. 18, p. 118-122.

[3] Information on: http: //www.119.gov.cn/xiaofang/hztj/36306_1.htm

[4] M. L. Li, Y. L. Yin, the Development and Research Status of Intelligent Fire Truck. Equipment Manufacturing Technology. Vol. 25 (2019) No. 06, p. 225-228.

[5] G. Kelly, a Theory of Personality. New York: Routledge, 1955, p. 101-103.

[6] M. Y. Ma, Y. C. Chen, and S. R. Li, How to build design strategy for attractiveness of new products (DSANP). Advances in Information Sciences and Service Sciences (AISS). Vol. 11 (2011) No. 03, p. 1-10.

[7] B. Y. Zhang, Preference-based Design: Study on Miryoku Engineering and its Application in Product Design. Art & Design. Vol. 295 (2017) No. 11, p. 136-137.

[8] Y. Z. Lu, J. Pei, Design Research on Neo-Chinese Style Range Hoods Based on Evaluation Grid Method. Journal of Graphics. Vol. 40 (2019) No. 06, p. 1109-1115.

[9] R. R. Yang, Design Research on Infusing Tea Machine Based on Evaluation Grid Method. Tea in Fujian. Vol. 40 (2018) No. 199, p. 173-174.

[10] L. Xi, Modelling Design of Mini Electric Vehicle Based on Attractive Factors. Journal of Graphics. Vol. 39 (2018) No. 4, p. 661-667.

[11] C. H. Ho, and K. C. Hou, Exploring the Attractive Factors of App Icons. KSII Transactions on Internet & Information Systems. Vol. 9 (2015) No. 09, p. 2251-2270.

[12] J. X. Han, and M. Y. Ma, The study of charm factor of stationery shop. Journal of Interdisciplinary Mathematics. Vol. 21 (2018) No. 02, p. 299-305.

[13] J. X. Han, and M. Y. Ma, Study on the Attractiveness Factors of Online Courses. Education Sciences. Vol. 9 (2019) No. 02, p. 128.

[14] G. F. Wu, W. F. An, and J. H. Liu, Practical Data Analysis Method. Beijing: China Statistical Publishing House, 1992, p. 300-341.

[15] C. Hayashi, on the quantification of qualitative datafrom the mathematic-statistical point of view. Annals of the Institute of Statistical Mathematics. Vol. 2 (1950) No. 01, p. 35-47.

[16] H. J. Wang, B. Y. Sun, J. J. Wang, et al. Methods supporting product modularization process design for mass customization. Computer Integrated Manufacturing Systems. Vol. 10 (2004) No. 10, p. 1171-1176.

[17] Q. Shi, Application Research on Product Modular Design. Design. Vol. 06 (2015) No. 23, p. 106-107.