ISSN: 2414-1895 DOI: 10.6919/ICJE.202205_8(5).0007

Concept Car Product Design based on Hierarchical Analysis Support Index System Construction and Application

Yujing He[1], Guankui Zhang[1], Aijia Wang[1], Kaile Ren[1], Hui Yu[2]

[1] School of Design Art, Lanzhou University of Technology, Lanzhou 730050, China

[2] School of Computer and Communications, Lanzhou University of Technology, Lanzhou 730050, China

Abstract

To assist companies in making rational decisions in the evaluation stage of concept car product design solutions and to reduce the subjectivity and blindness of concept car product design, a concept car product design support index system was constructed using expert evaluation and hierarchical analysis to study the concept car design preference considerations by comprehensively considering the influence of aesthetics, comfort, innovation and safety on concept car design. The study shows that in the concept car design support index evaluation system, the weight of each index on the concept car design is aesthetics (0.6006) > innovativeness (0.2400) > security (0.0989) > comfort (0.0605); In the secondary indicator evaluation system, the top five secondary indicators are ranked as styling proportions (0.2946) > line surfaces (0.1873) > technology Innovation (0.1684) > color design (0.1187) > braking performance (0.0641). The results of this study were also applied to the design of a new concept car.

Keywords

Concept Car; Product Design; Index System; Expert Evaluation; Hierarchical Analysis.

1. Introduction

With the development of society, the advancement of technology and the evolution of art, the demand for "beauty" in product design has become higher and higher. According to Y.Z. Li [1], design aesthetics refers to the beauty of function, science and technology. According to A.H. Zhao et al. [2], artistic beauty refers to the beauty of form and context, which are closely related and complementary to each other. W. Sun et al. [3] believe that the beauty of design is the pursuit of the integration of practical and aesthetic, material and spiritual, science and art. F.F. Liu [4] believes that the beauty of design refers to the harmonious beauty formed by the mutual influence of truth, goodness and beauty in order to develop together. For thousands of years, mankind's pursuit of beauty has never ended, and aesthetic design and beauty evaluation, as important factors to promote the development of aesthetic design, have gradually become a hot issue in design research.

The concept car is the "car of the future" between the ideal and the reality, through the advanced design to show people the engineer's thinking about the future of transportation and the combination of engineering beauty. With the introduction of Germany's "Industry 4.0" and "Made in China 2025" and other national-level manufacturing development strategies, the intelligent manufacturing of concept cars has become a common trend and goal of global manufacturing development. Concept car design, as the source of the production process of concept cars, occupies an increasingly large proportion. There are many factors to consider in concept car design, such as aesthetics, comfort, innovation and safety, etc. There is no complete evaluation system to support how to select these factors scientifically and reasonably, and how to make decisions on concept car design for specific

ISSN: 2414-1895 DOI: 10.6919/ICJE.202205_8(5).0007

brands of concept cars. In this paper, we establish a set of supporting index system for concept car design decision from the current situation of concept car design research, and apply this index system to concept car design to design a new concept car.

2. Current Status of Concept Car Design Research

X.X. Xu et al [5] summarized the design characteristics of human morphological features in concept car design by analyzing and extracting the design features of several latest concept cars, and proposed the design trend of human morphological bionic aesthetics in future concept car design; M.X. Yang et al. [6] analyzed the bionic features of lotus, and let it be reasonably used in the innovative design of concept car's form, function, structure and color. The bionic design method of concept car based on lotus characteristics is proposed, which provides a way to create concept cars with more natural characteristics and provides ideas to improve the design method of bionic aesthetics of concept cars; P.L. Li et al. [7] propose that the smoothness of car driving and the comfort of riding and driving should be considered in the design of concept cars; L. Ai [8] proposes that concept car design should reflect innovation through the analysis and research of concept cars in international auto shows. X.F. Huang [9] believes that in the 21st century, the design of concept cars should reflect the innovation of science and technology, and the design development of concept cars is bound to flourish with the innovation of automobile technology; Z.Y. Yan et al. [10] proposes that the design of concept cars should pay attention to safety by profoundly analyzing the characteristics of two kinds of accidents caused by human interference and natural disasters, and comparing the connection and difference between traditional driving and artificial intelligence driving. L. Zhang et al. [11] take the concept car "Nido" designed by Italian design company Pininfarina and the concept car XC60 designed by Volvo as examples, pointing out that the design of safety systems in the design of cars will be the focus of future car development.

Existing studies generally only elaborate the viewpoint of concept car product design from a single aspect, and do not comprehensively and systematically evaluate and analyze concept car product design. In order to comprehensively evaluate concept car product design solutions, entropy value method, gray correlation analysis and hierarchical analysis combined with expert evaluation can be chosen. The entropy method determines the indicator weights according to the degree of variation of the indicator values of each index, which is an objective weighting method and avoids the bias brought by human factors. However, the entropy method ignores the importance of the indexes themselves, and sometimes the determined index weights may be far from the expected results, and the entropy method cannot reduce the number of dimensions of the evaluation indexes. The gray correlation analysis method is based on the sample data of each factor with gray correlation to describe the strength, size and order of the relationship between factors. It has lower data requirements and less workload, and its main drawback is that it requires the current determination of the optimal value of each indicator, which is too subjective, while the optimal value of some indicators is difficult to determine, so its use is limited and the problems solved are limited. Therefore, based on the existing research, this paper uses expert evaluation and hierarchical analysis to conduct a comprehensive, systematic, scientific and objective study of concept car product design.

3. Concept Car Product Design Program Support Indicator System Study

3.1 Research Methodology

An evaluation study of concept car product design using expert evaluation and hierarchical analysis. Hierarchical analysis is a multi-objective decision analysis method proposed by T.L. Saaty, an American operations researcher, in the early 1970s. By decomposing the elements related to decision making into levels of objectives, criteria, and options, quantitative and qualitative analyses are conducted to finally determine the decision options[12].

ISSN: 2414-1895 DOI: 10.6919/ICJE.202205_8(5).0007

3.2 Building a Structural Model

With the optimal solution of concept car product design as the research objective, the evaluation model of concept car product design is established with aesthetics, comfort, innovation and safety as the evaluation indexes. Aesthetics include color design, curved lines, and shape proportion; comfort includes space size, ride experience, light and dark; innovation includes technical innovation, structural innovation, and shape innovation; safety includes field of view, ease of operation, and braking efficiency. The model is shown in Figure 1.

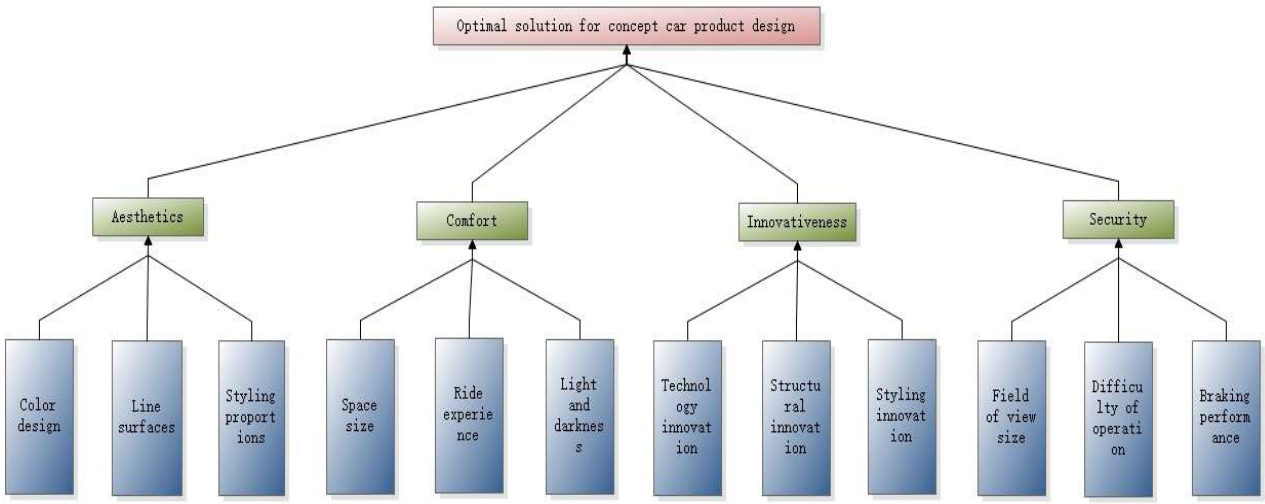

Figure 1. Concept car product design evaluation support index system model.

3.3 Constructing the Judgment Matrix

The individual evaluation indicators in the evaluation indicator layer do not necessarily have the same weight in the study objectives, and each of them has a certain proportion in the mind of the decision-making expert. The numbers 1 to 9 and their reciprocals are cited as scales to define the judgment matrix A = (aij)n×n. The judgment matrix scales are defined as shown in Table 1.

Table 1. Definition of judgment matrix scales

Scale	Definition
1	Factor i is as important as factor j
3	Factor i is slightly more important than factor j
5	Factor i is significantly more important than factor j
7	Factor i is very important than factor j
9	Factor i is heavily important than factor j
2, 4, 6, 8	Denotes the middle value of the above adjacent judgments
Countdown	Factor j is critical relative to factor i

3.4 Consistency Test

(1) Calculation of consistency index CI

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{1}$$

Where λmax is the maximum eigenvalue of the judgment matrix [12].

ISSN: 2414-1895 DOI: 10.6919/ICJE.202205_8(5).0007

(2) Find consistency indicators RI (see Table 2)

Table 2. Average random consistency index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RI	0	0	0.52	0.89	1.12	1.24	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58

(3) Calculate the consistency ratio CR

$$CR = \frac{CI}{RI} \tag{2}$$

When CR < 0.10, the consistency of the judgment matrix is considered acceptable; Otherwise, appropriate corrections should be made to the judgment matrix [12].

3.5 Calculation of the Weight Vector *W*

Since each column in the judgment matrix A approximates the distribution of the weights, the arithmetic mean of all the column vectors can be used to estimate the weight vector, i.e., Wi [12].

$$W_i = \frac{1}{n}\sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}},\ i = 1,2,\dots,n \tag{3}$$

4. Calculation Results and Application of Concept Car Product Design Solution Support Index System

4.1 Calculation Results of Supporting Index System

On the basis of the existing research, combined with expert assessment, the judgment matrix is constructed for the evaluation indicators and index rules of the concept car product design scheme, and the judgment matrix weight calculation and consistency indicators are shown in Table 3.

According to the calculation results of the first level consistency ratio of evaluation indexes and the second level consistency ratio of index rules, the calculation results are less than 0.10, which means that the assignment and ranking of the judgment matrix of evaluation indexes and index rules are valid and have good consistency, and the judgment matrices all meet the requirements. According to the evaluation index weights, the order of importance of the evaluation of concept car product design solutions is aesthetics (0.6006) > innovativeness (0.2400) > security (0.0989) > comfort (0.0605), thus it can be seen that in concept car product design, aesthetics and innovation are particularly important, and we should focus on concept car aesthetics and innovation, followed by concept car design. When we design a concept car, we should focus on the aesthetics and innovation of the concept car, followed by safety and comfort. According to the overall weight of the indicators, the order of the secondary indicators in the concept car product design is styling proportions (0.2946) > line surfaces (0.1873) > technology Innovation (0.1684) > color design (0.1187) > braking performance (0.0641) > styling innovation (0.0512) > ride experience (0.0447) > difficulty of operation (0.0227) > Structural innovation (0.0205) > field of view size (0.0121) > Space size (0.0101) > Light and darkness (0.0057). This shows that Styling proportions, Line surfaces and technical innovation of the concept car have more influence on the design of the concept car, while the view size, space size and Light and darkness have less influence on the design of the concept car.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202205_8(5).0007

Table 3. Weighting of supporting indicators for concept vehicle product design solutions

Research Objectives	Evaluation Indicators	Weighting value	Proportion of first-level consistency	Secondary indicators	Weighting value	Proportion of second-level consistency	Combined weights
Optimal solution for concept car product design	Aesthetics	0.6006	0.0456	Color Design	0.1976	0.0517	0.1187
				Line surfaces	0.3119		0.1873
				Styling proportions	0.4905		0.2946
	Comfort	0.0605		Space size	0.1676	0.0137	0.0101
				Ride Experience	0.7380		0.0447
				Light and darkness	0.0944		0.0057
	Innovativeness	0.2400		Technology Innovation	0.7014	0.0313	0.1684
				Structural innovation	0.0853		0.0205
				Styling Innovation	0.2132		0.0512
	Security	0.0989		Field of view size	0.1222	0.0036	0.0121
				Difficulty of operation	0.2299		0.0227
				Braking Performance	0.6479		0.0641

4.2 Supporting the Application of the Index System

Based on the calculation results of the weighting of the concept car product design elements, a new concept car is designed by applying the product design process and methods and combining the research results with design practice. The concept car has an atmospheric shape, dynamic lines, bold innovative design, beautiful color painting, and a body design full of modern atmosphere and sporty aesthetics, which retains the nobility of classical aesthetics while skillfully applying bionic aesthetics. The design effect is shown in Figure 2.

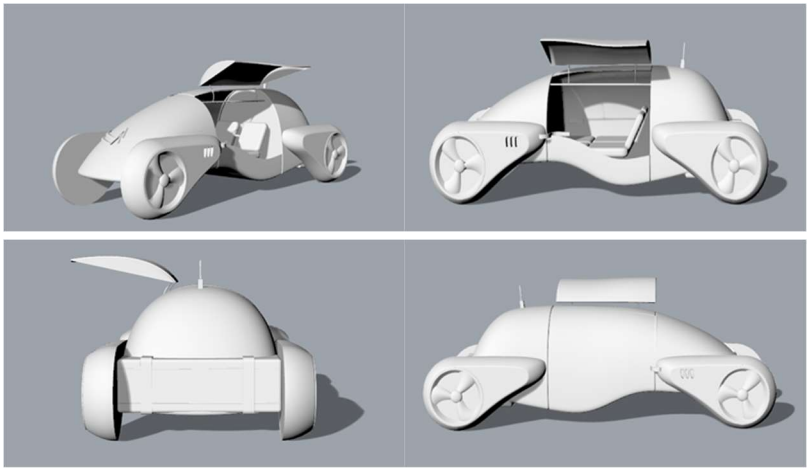

Figure 2. Concept car product design rendering

ISSN: 2414-1895 DOI: 10.6919/ICJE.202205_8(5).0007

5. Conclusion

In this paper, based on the current status of concept car product design research, knot and expert evaluation, with the purpose of selecting the optimal design scheme of conceptual vehicle product, the support index system of conceptual vehicle product design is established, which provides a theoretical basis for enterprises to decide the optimal concept car product design. When conducting concept car product design, designers should focus on concept car shape proportion, line curves, technical innovation and color design, while the design requirements for concept car view size, space size and light and darkness are low. Finally, based on the product design process, combined with the results of the concept car product design evaluation index research, a new concept car is designed, and the designed product basically meets the current public aesthetic standards and industrial aesthetics requirements.

References

[1] Y.Z. Li. On the "three beauties" in design aesthetics, Journal of Yellow River University of Science and Technology, vol. 01 (2003), 59-67.

[2] A.H. Zhao, D.M. Li, H.Y. Hu, et al. An analysis of the formal and contextual beauty of garden plant landscape, Journal of Northwest Forestry College, vol. 04 (2004), 170-173.

[3] W. Sun, W.J. Li, Y.L. Feng. Exploration of design under the concept of truth, goodness and beauty, Journal of Huangshan College, vol. 19 (2017), 98-100.

[4] F.F. Liu. The truth, goodness and beauty of urban design, Beauty and Times, vol. 01 (2015), 54-56.

[5] X.X. Xu, H.B. Wang. Analysis of concept car modeling design based on human morphological bionic, Industrial Design, vol. 07 (2018), 147-148.

[6] M.X. Yang, C.D. Wang. Study on the bionic design of concept car based on lotus characteristics, Packaging Engineering, vol. 41 (2020), 218-227.

[7] P.L. Li, Z.C. Li, Q Li. Research on the evaluation method of automobile comfort, Agricultural Mechanization Research, vol. 06 (2004), 103-104.

[8] L. Ai. Concept cars:Innovation to meet the future, Special Purpose Vehicles, vol. 01 (2012), 59-61.

[9] X.F. Huang. The concept car leading the development of future cars, Science and Technology Venture Monthly, vol. 09 (2004), 72-73.

[10] Z.Y. Yan, C. lu, Q. Zeng. A first look at the design concept and outlook of 2028Sunny concept car, Modern Business, vol. 09 (2019), 182-183.

[11] L. Zhang, K.W. Liu. An important link in automobile development: safety design, Decoration, vol. 04 (2009), 30-31.

[12] X. Deng, J.M. Li, H.J. Zeng, et al. Analysis of analytic hierarchy process weight calculation method and its application research, The practice and understanding of mathematics, vol. 42 (2012), 93-100.