FAHP-Based Weighting Analysis of Automotive Seat Comfort Evaluation Index

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Abstract

In this paper, a comprehensive quantitative evaluation and analysis of the evaluation index of the automotive seat comfort design from the aspects of operating comfort, static comfort and dynamic comfort. Around the driving comfort of the car, based on the full reading, analysis of literature and theoretical deductions, Through expert interviews and reliability analysis of the survey results, 28 design indicators were found from the headrest, backrest, lumbar support, seat surface and overall perception of the seat. And using the fuzzy analytic hierarchy process to analyze the weights of all levels of evaluation indicators, providing a more detailed reference index system for the comfort design of the car driving seat.

Keywords

Car seat, Ride comfort, Reliability Analysis, FAHP.

1. Introduction

With the rapid development of the automotive industry, consumer expectations for automotive performance have changed, and many automotive brands have taken the driving quality of the car as an important selling point. As one of the people's main travel tools, improving the ride comfort of the car brings higher enjoyment and happiness to the user while also greatly reducing the physical and mental fatigue caused by long-distance driving. Relieve potential diseases such as periarthritis and cervical spondylosis caused by driving, and reduce the occurrence of traffic accidents. On the contrary, bad seat design will accelerate these hazards. Therefore, the study of the comfort of the driver's seat in a car is of great significance.

In the survey and study of Magnusson and Wilder, it was found that when the driver judged the comfort of a journey, he mentioned many influencing factors, such as the scenery along the way, his own mental state, his traveling companions, and the status of the road, even The effectiveness of fuel. However, from the feeling of the driver himself, almost all car drivers think that they have a well-designed seat, the space in the car is large enough, and the noise emitted by the car during the driving process is very low. Very comfortable. The design of automotive driver's seats is very similar to that of other products. They communicate with each other through symbols and symbols to reach a consensus with the audience. It not only has the meaning of indicating and implying double-level meaning, but also Through the combination of aesthetic form and formal beauty and color science, the communication and communication of semantic transmission with audiences. [1]

2. Organization of the Text

2.1 Car Seat Comfort Analysis

2.1.1 Car Seat Comfort

Car ride comfort includes static comfort and dynamic comfort as well as comfort. . The former is mainly related to dimensional parameters, surface quality, and adjustment characteristics, and the latter is mainly related to vibration characteristics.[2]The influence factors of the comfort of train passenger seats are divided into subjective views (including various objective dynamic physical properties such as speed, vibration, noise, temperature and air pressure in the train running on the human body; ride comfort;) and objective (passengers are Experience the degree of satisfaction with subjective feelings such as seat scale, functional layout, surface material texture, shape and color during the use of the seat). Because the use groups of train seats and the use groups of car seats have great similarities, passengers with more popular features and different characteristics have different experience for various factors affecting the comfort of the seats. These comfort factors also have certain complexity and ambiguity.[3]

2.1.2 Analysis of Design Factors of Car Seat Comfort

In the study of the comfort design of the car seat, the morphological analysis method was introduced into the behavior analysis of the occupants under static, dynamic and maneuvering conditions. According to the actual structure of the driver's seat, the seat is divided into five parts: the headrest, the backrest, the lumbar support, the seat and the overall feeling. Each part needs to be comprehensively considered from the objective conditions of the seat's physical dimensions, safety, functionality, and operability, as well as the subjective needs of the riding expectations and aesthetic elements. These elements are associated with passengers and seats, see Figure 1.

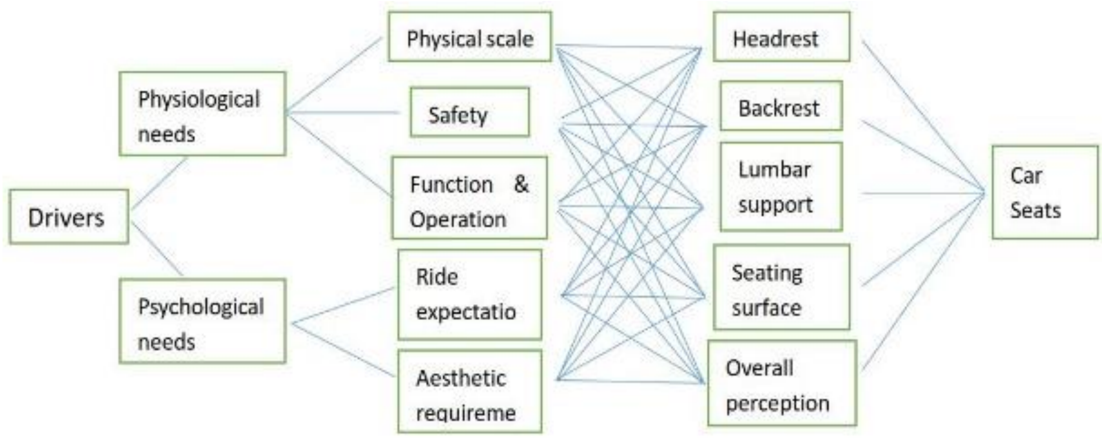

Fig. 1 Car seat comfort element correspondence analysis diagram

2.2 The Construction of Car Seat Comfort Evaluation Index

The biggest problem with the AHP is that it is difficult to ensure the consistency of thinking at a certain level when there are many evaluation indicators (for example, more than four). In this case, the fuzzy analytic hierarchy process (FAHP), which combines the advantages of the fuzzy method and the analytic hierarchy process, will be able to solve this problem well. Therefore, this paper will use the fuzzy hierarchical analysis method to analyze the seats. The importance of comfort index issues.

2.2.1 Evaluation Index Collection and Classification

On the basis of full reading and analysis of literature and theoretical deductions, according to the seat data collected in the previous period, the four parts of the headrest, backrest, lumbar support, and seat surface are measured according to physical dimensions and safety from both the passenger and the seat. In terms of sex, function and operation, riding expectation, and aesthetic elements, 35 evaluation indexes affecting the comfort of car seats were initially extracted. The fuzzy level analysis method is used to classify the car seat comfort index into three levels: the overall comfort of the car seat is evaluated as the target level L, the level 1 indicator level is the criterion level M, and the level 2 criterion level is the indicator level N. The seat comfort design elements satisfying the passenger demand are taken as the criterion layers, namely: the headrest M1, the backrest M2, the lumbar support M3, the seat M4, the overall perception M5. All indexes covering the seat comfort through the criterion layer Divided into two levels of indicators.

(1) The head restraint M1 contains the following indicators: N1 cervical comfort, N2 height adjustment, N3 head pressure distribution, N4 headrest contouring, N5 transverse and longitudinal curvature, N6 fabric feel, N7 support structure stability, N8 head Pillow position adjustment.

(2) The indicators included in the backrest M2 are: N9 backrest height, N10 backrest width, N11 backrest surface, N12 thoracic spine comfort, N13 fabric breathability, N14 backrest tilt adjustment, N15 inclusiveness (package).

(3) The indicators contained in the lumbar support M3 are: N16 lumbar support thickness, N17 lumbar support width, N18 lumbar support height, N19 softness and stiffness, N20 position adjustment, N21 lumbar comfort, and N22 fit.

(4) Seat M4 contains indicators: N23 seat height, N24 width, N25 depth, N26 seat curvature, N27 height adjustment, N28 front and rear adjustment, N29 pressure distribution comfort, N30 tail comfort, N31 seat Air permeability.

(5) The overall perception M5 contains the indicators: N32 shape, N33 color, N34 smooth surface, N35 exquisite sense, N36 sense of the times, N37 material, N38 space to accommodate sense.

2.2.2 Questionnaire Reliability Analysis

The 38 indicators collected were made into the form of a questionnaire, and it was investigated whether each indicator N was suitable for the ride comfort index under its corresponding indicator M. The questionnaire selects the Rickett scale and asks each subject to indicate his or her attitude towards each item. It is expressed in numerical form. [4] This paper adopts the fifth-order scale:

1.Strongly agree 2. Agree 3. Nothing 4. Do not agree 5. Strongly disagree

In this survey, a total of 20 questionnaires were distributed, 16 questionnaires were available for recovery, and the rate of return of the questionnaires was 80%. The ratio of men to women was 1:1, and the age was between 20-40 years old.

In order to avoid the influence and interference of the error factors in the questionnaire, to eliminate the defects and deficiencies of the questionnaire design as much as possible, and to ensure the stability of the measurement results of the comfort evaluation, a questionnaire survey was conducted on the questionnaire, and the statistical data was analyzed by SPSS. Cronbach alpha reliability coefficient is currently the most commonly used reliability coefficient, and its formula is:$\alpha = (k/(k-1)) * (1-(\sum S_i^2)/S_T^2)$. Among them, k is the total number of items in the scale, S_i^2 is the in-the-term variance of the i-th item score, and S_T^2 is the variance of the total score of all item items. From the formula, it can be seen that the α coefficient evaluates the consistency between the scores of the items in the scale, which is an intrinsic consistency coefficient. This method is applicable to the reliability analysis of attitudes and opinion questionnaires (scales).

The method used for the calculation is:

(1) Classify the problem according to the framework and calculate the value of a;

(2) Remove the problem of heightened barriers;

(3) and so on, until the value is no longer increased after deleting the problem.

The analysis results are shown in Table 1.

Table 1 Questionnaire Reliability Analysis results

Cronbach' Alpha	The number of items
.758	38

The reliability coefficient of the total table is better than 0.8 and 0.7-0.8. The reliability coefficient of the subscale is better than 0.7 and 0.6-0.7 is acceptable. If Cronbach's alpha coefficient is below 0.6, consider re-rating the questionnaire.[5]The reliability analysis has a value of 0.758, which indicates that there are problems in the rationality of some of the questions. The analysis of the reasons for deletion helps to increase the rationality of the questionnaire design and the accuracy of the comfort model construction. After revising the related issues of the secondary indicators N1, N10, N22, N27, N33, and N34, 20 questionnaires were again issued, 18 questionnaires were available for recovery, and the questionnaire recovery rate was 90%, of which the male to female ratio was 1:1 and the age was Between 20-40 years old.The reliability analysis of the survey results of the second questionnaire yielded a value of 0.884, indicating that the questionnaire design was reasonably available.

2.2.3 Indicator Selection

In order to further optimize the design indicators and improve the accuracy of the indicators, the average of the survey data of the above-mentioned reliable questionnaires was calculated. According to the requirements of the questionnaire survey, the data with larger values can be considered as indicators that are not suitable for driving comfort.,see Table 2.

Table 2. Second-level Indicator Average statistics

Headrest	mean	Backrest	mean	Lumbar support	mean	Seating surface	mean	Overall perception	mean
N1	1.2	N9	2.3	N16	1.8	N23	2.5	N32	1.5
N2	2.3	N10	1.7	N17	1.9	N24	1.8	N33	1.7
N3	1.9	N11	1.3	N18	1.7	N25	1.8	N34	1.9
N4	2.1	N12	2.5	N19	1.6	N26	2.3	N35	1.5
N5	1.7	N13	1.5	N20	1.8	N27	1.2	N36	2.5
N6	1.8	N14	1.2	N21	2.3	N28	1.2	N37	1.9
N7	2.3	N15	1.6	N22	1.9	N29	1.6	N38	2.7
N8	1.7					N30	1.4		
						N31	1.7		

According to the requirements of the questionnaire, the meanings represented by the values are 1. Strongly agree 2. Agree 3. Don't care 4. Disagree 5. Disagree strongly. In order to ensure the accuracy of the indicator, indicators with an average greater than 2 should be removed: N2,N4, N7, N6 ,N12, N21, N23, N26, N36,N38, the remaining indicators can be used as an influencing factor affecting the seat comfort of the car driving position.

2.3 FAHP Construction Based on Car Seat Comfort Evaluation Model

2.3.1 Establish a Hierarchy of Indicators.

The index set U={u1,u2,...,un} is established according to the analytic hierarchy process. According to the nature of the target decision and the interrelationship between the factors, the indicators are divided into layers. According to the relationship and nature of the indicators, the indicator set is divided into a number of indicators. Each indicator of level 1 is further divided into a number of indicators of level 2 and the hierarchical structure of indicators is finally constructed.

2.3.2 Construction and Calculation of Weights.

Introducing a fuzzy subset B of lower-level indicators in U B={B1 B2,...,Bm}, and the relative importance of factors Bi in B subset to Bj is recorded as bi j(i,j=1,2,... ,m), and combined Saaty's 1~9 grade importance scale method to compare the factors in fuzzy subset B with the importance level in the previous layer, thus constructing the judgment matrix V as:

$$\nu = \left(b_{ij}\right)_{m\times n}\begin{bmatrix} b_{11} & \cdots & b_{1m} \\ \vdots & & \vdots \\ b_{m1} & \cdots & b_{mm} \end{bmatrix} \tag{1}$$

In the formula: m—the number of indicators in fuzzy subset B.

The feature vector ω of the judgment matrix ν is calculated, and the normalized process is applied to satisfy the formula (2) to obtain the weight of each element in B.

$$\sum_{i=1}^{m} w_i = 1 \tag{2}$$

Find the maximum eigenvalue λmax of the judgment matrix ν, and check the consistency of the weights. Calculate the consistency index (CI) by formula (3), and compare the values of the random consistency index (RI) . When the random consistency ratio CR=CI/RI<0.1, the judgment matrix V is considered satisfactory. The consistency, otherwise need to readjust the judgment matrix.

$$CI = \frac{\lambda_{max}-m}{m-1} \tag{3}$$

2.3.3 Fuzzy Comprehensive Evaluation.

Set the comment set E={e1,e2, ...,ek}, where ef(f=1,2,...,k) is the f-th comment of the k-class evaluation criteria. Each single factor index in the fuzzy subset is evaluated and counted to obtain the degree of membership r of the factor index in the rating hierarchy. A membership matrix consisting of various factors, namely the fuzzy evaluation matrix R.

$$R = \left(r_{if}\right)_{m\times k} = \begin{bmatrix} r_{11} & \cdots & r_{1k} \\ \vdots & & \vdots \\ r_{m1} & \cdots & r_{mk} \end{bmatrix} \tag{4}$$

In the formula: r_{if}——The degree of membership of evaluation factor f is given to factor Bi;

k——The number of reviews for the factor Bi.

According to the formula (5), the single-factor fuzzy comprehensive evaluation calculation is performed by using the known fuzzy subset weight vector A=(a1, a2, ... am) and the fuzzy evaluation matrix R to obtain the evaluation result vector of the criterion layer and the target layer respectively. C. Finally, according to the principle of maximum degree of membership, the evaluation results are selected and evaluated.

$$C = A \times R = (a_1, a_2, \cdots a_m) \times \begin{bmatrix} r_{11} & \cdots & r_{1k} \\ \vdots & & \vdots \\ r_{m1} & \cdots & r_{mk} \end{bmatrix} = (c_1, c_2, \cdots, c_k) \tag{5}$$

In the formula: cf——Degree of Membership Function, f=1, 2, ..., k.

2.3.4 Car Seat Comfort Index Weight Calculation

The index of car seat comfort is composed of the target layer (the total comfort of the driver in the car), the criteria layer (M1 to M5), and the indicator layer (N1 to N36). A judgment matrix for each factor of the second-class seat is established, and according to formulas (1)-(3), the second-class seat comfort index layers N1-N10, N11-N14, N15-N24, N25-N29 can be calculated respectively. The weight vectors A1, A2, A3, A4, and A5 of the sum N30 to N35 and the weight vector A6 of the criteria layers M1 to M5. The assessment of seat comfort was scored by a total of 6 seat designers, research institution experts, and corporate engineers. The result of the calculation is as follows:

A1=(0.42, 0.16, 0.06, 0.10, 0.26) λmax=5.32 CR=0.08

A2=(0.10, 0.30, 0.06, 0.26, 0.28) λmax=5.12 CR=0.03

A3=（0.06, 0.05, 0.04, 0.49, 0.12, 0.24） λmax=1 CR=0

A4=（0.12, 0.09, 0.06, 0.07, 0.09, 0.19, 0.37） λmax=1 CR=0

A5=（0.37, 0.22, 0.30, 0.04, 0.07） λmax=1 CR=0

A6=（0.15, 0.26, 0.07, 0.48, 0.04） λmax=5.2 CR=0.05

A1 ~ A6 consistency check, because the CR value of each judgment matrix is less than 0.1, indicating that the degree of consistency meets the requirements.

M1 Headrest: Cervical Comfort> Headrest Position Adjustment> Pressure Distribution> Fabric Touch> Contact Curvature.

M2 backrest: backrest surface> inclusive (wrap)> backrest tilt adjustment> backrest width> fabric breathability.

M3 lumbar support: hardness and softness> Laminating> Position adjustment> Lumbar support thickness> Lumbar support width> Lumbar support height.

M4 seat: seat breathability> coccal comfort> seat width> seat depth = seat pressure distribution> front and rear adjustment> height adjustment.

M5 overall perception: Modeling> Materials> Colors> Refined> Surface fluency.

M6 level indicator: seat seating> backrest> headrest> lumbar support> overall perception.

3. Conclusion

For a more comprehensive and objective evaluation of the comfort design of the car seat, the car seat structure is split based on the morphological analysis method, and the ride demand of the driver is analyzed from different structural angles. From the headrest of the seat, the backrest, the lumbar support surface and the overall perception of the five aspects, an index construction framework that affects the comfort of the car seat is established. Based on the analytic hierarchy process and the principles of fuzzy mathematics, the comprehensive evaluation model and evaluation process of high-speed train seat comfort are constructed. The seat comfort evaluation model based on the analysis of the car seat structure was used to evaluate the indexes that affect the seat comfort. Through the analysis of the evaluation results, it is possible to design not only a seat scheme with higher overall comfort, but also a detailed analysis of seat design factors that affect comfort, and facilitate the proposal of design improvement. The evaluation model can provide a reference for the seat design evaluation and the selection of the company.

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