

Application of AHP in Function Optimization Design of Tachograph

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Abstract

Objective Improve the efficiency of product design of tachograph. **Method** Taking the main functions of the tachograph as the experimental research object, this paper uses the Analytic Hierarchy Process (AHP) to rank the importance of the main functions of the tachograph in the form of questionnaire and interview. **Result** By ranking the importance of representative functions of tachograph, it is found that users pay more attention to fatigue driving warning function and ADAS driving assistance function. When designing and publicizing related products, they should be put in the first place to enhance the competitiveness of products. **Conclusion** Through the application of Analytic Hierarchy Process, a quantitative decision-making basis is provided for product function positioning, which makes the design process more reasonable and efficient.

Keywords

Product design; Tachograph; Analytic hierarchy process; Function optimization.

1. Introduction

With the continuous increase of the number of cars at home and abroad, people have higher and higher requirements for the practicability and beauty of the tachograph. With the progress of technology, the number of functions of dash cam is also increasing. In order to meet the needs of different consumers, manufacturers put a large number of functions into their products, which not only improves the competitiveness of products, but also improves the complexity of product operation. [1] The cognitive resources of drivers are limited, and the products that need complex operation will increase their cognitive load and affect the driving safety. By sorting the main functions of the dash cam user demand, and taking the important functions as the design focus, it can effectively improve the use experience and efficiency of the product, reduce the complexity of the product, and reduce the cognitive load of the user using the product. Therefore, it is of great significance to optimize the main functions of tachograph. [2]

2. Function overview of tachograph

The tachograph has the following functions: it has the function of data recording, which can record the driving speed of the car, the internal and external environment of driving, driving track, recording, etc.; it has the function of gravity induction, when the car is subject to severe vibration, such as collision accident, the recorded data will be locked to prevent erasing and covering; it has the function of data analysis, and sends it to the driver through visual or auditory stimulation Provide safety tips, such as speeding, overtime, fatigue driving, abnormal speed status, etc.; with advanced driving assistance system, detect pedestrians or objects around the vehicle, and give early warning of potential dangers. In addition, the device can update the video export system through SD card, USB and wireless transmission. [3] Through recording the video images and recording of the whole driving process of the vehicle, the tachograph provides effective evidence for the analysis and identification of traffic accidents.

3. Research status

At present, most of the domestic driving recorders mainly use camera recording function to meet the basic needs of users for driving records, supplemented by voice broadcast, fatigue driving warning, ADAS auxiliary driving system and other functions to improve the user experience. [4]

The traditional usability evaluation methods of tachograph include heuristic evaluation, performance test and so on. These methods rely on the knowledge and experience of evaluators, and are easily disturbed by external environment. In contrast, the function ranking based on AHP is relatively objective and accurate, which can reduce the experimental error and subjective influence.

Based on the analytic hierarchy process (AHP), according to the interaction between users and products, combined with user interviews, this paper discusses users' subjective feelings about the use of products, and makes quantitative analysis on the importance of representative functions of tachograph.

4. Overview of analytic hierarchy process

4.1 The concept of analytic hierarchy process

Analytic hierarchy process (AHP) is a multi-objective decision analysis method, It was put forward by American operational research scientist Professor Saaty of Pittsburgh University in 1970s. It is a method that divides complex decision-making into different levels and factors, compares the importance of two factors relative to a factor at the upper level, establishes a judgment matrix, and calculates the maximum eigenvalue and corresponding eigenvector of the matrix to obtain the importance degree of different schemes to decision-making objectives The weight provides the basis for the selection of the best scheme. [5]

4.2 The basic principle and steps of analytic hierarchy process

It can be divided into the following four steps: (1) constructing the hierarchical structure model, including the target level, the criterion level and the scheme level; (2) constructing all the judgment matrixes in each level; (3) the hierarchical single ranking, which can obtain the relative importance of a certain level factor relative to a certain factor in the previous level; (4) the total ranking of the hierarchy, The order of importance of all the bottom factors relative to the top-level objectives is calculated.[6]

5. Application of analytic hierarchy process in function optimization design

5.1 User interview

User interview is a widely used means in the actual investigation and research. The purpose of user interview in this paper is to find the user's requirements for different functions of the tachograph through user feedback as far as possible, so as to provide guidance for the subsequent design of hierarchical structure model.[7]

A total of 20 users with more than 5 years' driving experience were selected in this interview, with a gender ratio of 1:1. Their occupations include didi taxi driver, college students and graduate students, and all of them have used the tachograph.

The main content of the interview is the user's evaluation and expectation of the function of the tachograph; the factors affecting the experience found in the process of using the product; what are the most commonly used functions; and what shortcomings of the product need to be improved.

Through the user interview, the user's requirements and expectations for the function of the tachograph are obtained, and four categories of humanization, safety, aesthetics and functionality are summarized

Humanized design means people-oriented design. For example, voice broadcast function can reduce the number of driving tasks; it supports wireless transmission function, which can facilitate users to access vehicle data recorder by supporting wired, wireless and other transmission modes. In the design process, we should firmly grasp the driver's behavior habits and psychological

characteristics, and carry out targeted design, so that the product can not only meet the driver’s physiological needs, but also meet their psychological characteristics, so as to bring users a pleasant and comfortable use experience.

In terms of safety, the interviewees agreed that the installation of the product should be convenient and firm, and the product should not fall off due to the vibration caused by driving for a long time. The product should be round and light without sharp edges and corners. ADAS driving assistant system and fatigue driving warning device are equipped to reduce the hidden danger in the process of driving.

Aesthetics refers to the combination of color matching, shape, line and other design elements with the user’s perceptual cognition to make the product appearance design elements more attractive to consumers and close to the weight requirements of users’ psychology. While paying attention to the aesthetic needs of users, the uniformity of the lines and color matching of the appearance of the dash cam with the driving environment will also affect the unity of the space. [8] The consistent style in the cab can effectively reduce the visual interference and improve the driving safety.

In terms of functionality, the hardware configuration should be sufficient for the smooth operation of the system, the camera should meet the requirements of all-weather road condition recording, the night driving recorder should be able to shoot clearly, and the product should have wide-angle imaging distortion optimization and anti shake function to ensure the imaging stability.

Through the summary and analysis of the above results, the first-class factors affecting the user’s use of the tachograph are extracted as follows: humanization, safety, aesthetics and functionality.

The secondary influencing factors are: wireless transmission function, voice broadcast function, fatigue driving warning function, ADAS driving assistance function, mellow and streamlined design, cab style integration, image distortion algorithm optimization, front and rear dual recording function. Among them, each primary factor corresponds to multiple secondary factors, and each secondary factor may also correspond to multiple primary factors at the same time.

5.2 Construct hierarchical model

The decision-making goal of this paper is to sort the functions of the tachograph according to the degree of user demand. The function and user demand of the existing tachograph in the market are analyzed and synthesized through the user interview, and several representative function composition scheme layers are obtained. The obtained hierarchical structure model is shown in Figure 1.

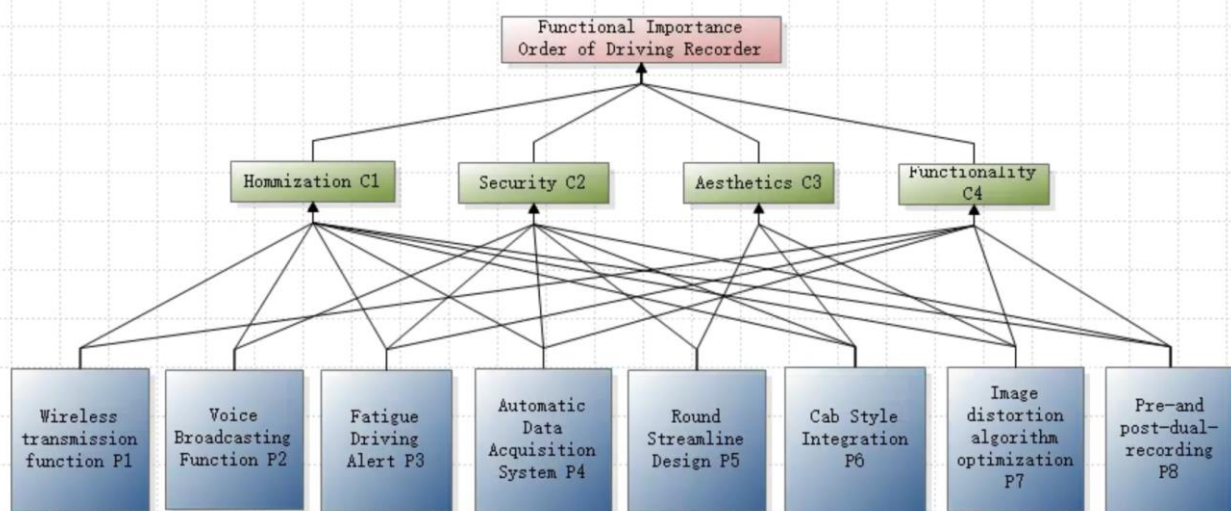


Fig.1 Hierarchical model

5.3 Construct judgment matrix

In order to get more objective evaluation results for each function, the scale method of 1-9 and its reciprocal is used to compare the two indexes in this structural model. Six designers and users assign values to each index through questionnaire, and obtain the weight of each index.

For n elements, the judgment matrix $C = (C_{ij})_{n \cdot n}$. The scale definition of judgment matrix is shown in Table 1.

Tab.1 Scale definition of judgment matrix

	Importance level	CNM assignment
1	i. The two elements are equally important	1
2	Element I is slightly more important than element J	3
3	Element I is more important than element J	5
4	Element I is more important than element J	7
5	Element I is more important than element J	9
6	Element I is slightly less important than element J	1/3
7	Element I is less important than element J	1/5
8	Element I is stronger than element J and is not important	1/7
9	I element is less important than j element	1/9

5.4 Data acquisition and calculation

In order to get more objective evaluation results for each function, in this structural model, according to the definition of matrix scale in Table 1, the scale method of 1-9 and its reciprocal is used to make the relative comparison between two indexes. It was completed by 6 designers and 4 users (average age 30 years old, male female ratio 1:1). The judgment matrix input is shown in table 2-6

Tab.2 The comparison of importance between primary factors

	C1	C2	C3	C4
C1		1/7	1/3	1/3
C2			8	7
C3				1/2
C4				

Tab.3 The comparison of the importance between the secondary factors on humanization

	P1	P2	P3	P4	P6	P7	P8
P1		2	1/3	1/5	2	1/3	1/4
P2			1/4	1/6	2	1/3	1/5
P3				2	3	3	2
P4					3	2	3
P6						1/3	1/6
P7							1/4
P8							

Tab.4 The comparison of the importance of secondary factors on safety

	P2	P3	P4	P5	P6	P8
P2		1/3	1/3	1/2	1	1/5
P3			3	5	4	5
P4				4	4	2
P5					2	1/4
P6						1/2
P8						

Tab.5 The comparison of the importance of secondary factors on Aesthetics

	P5	P6	P7
P5		1/2	1/4
P6			1/3
P7			

Tab.6 The comparison of the importance of secondary factors on functionality

	P7	P8	P1	P3	P4
P7		1/2	3	1/3	1/6
P8			4	2	1/2
P1				1/5	1/4
P3					1/2
P4					

Use to indicate the function of tachograph, The comparison results of users& apos; needs at the same level constitute a judgment matrix, and the corresponding characteristic equation of the judgment matrix is as follows:

$$AW = \lambda \max W \tag{1}$$

Where is the largest eigenvalue of the judgment matrix, is the eigenvector, the eigenvector is normalized, which is the relative weight value of user requirements W [9].

5.5 Consistency test

Because the judgment matrix is mainly based on subjective scoring, the complexity of objective things and the diversity of cognition of different people will lead to the deviation of consistency of the given judgment matrix, and the consistency of the judgment matrix affects the effectiveness of the decision-making results. Therefore, it is necessary to check the consistency of the judgment matrix and check the random consistency ratio. When < 0.1, the consistency of the judgment matrix is considered to be acceptable By. When ≥ 0.1, the judgment matrix should be modified appropriately. [10]

$$CI = \frac{\lambda \max - n}{n - 1} \tag{2}$$

$$CR = \frac{CI}{RI} \tag{3}$$

Among CI is the consistency test index; n is the judgment matrix, A is the number of factors contained in the hierarchy; RI see Table 7. Through the above analysis and calculation, the weight of each user demand is obtained w_1 .

Tab.7 Average Random Consistency Index

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

5.6 Function importance ranking of tachograph

The analytic hierarchy process (AHP) is used to analyze the importance of the representative functions of the tachograph. After the evaluation results are collected and sorted out, the maximum eigenvalue and eigenvector are solved according to the formula (1), (2) and (3). After the eigenvector is normalized, the importance weight of each representative function is obtained, and the value is less than 0.1, which conforms to the consistency inspection standard.

After calculating the composite weight of each layer factor to the target layer, the weight data is arranged in order from large to small. The results are shown in Table 8.

Tab.8 Function importance ranking of tachograph

Representative functions	weight
Fatigue driving warning P3	0.3147
Adas driving aid P4	0.2217
Front and rear dual recording function P8	0.1659
Image distortion algorithm optimization P7	0.0919
Integrated cab style P6	0.0728
Round and streamlined design P5	0.0722
Voice broadcast function P2	0.0481
Wireless transmission function P1	0.0126

5.7 Function optimization design of tachograph

Through the calculation and ranking of representative function weights, it can be seen that "fatigue driving early warning" accounts for the highest weight and should be developed in the functional design. The second is "ADAS driving assistance" and "front and rear dual recording function", "image distortion algorithm optimization" and "cab style integration" ranked the last two.

6. Conclusion

Through the weight analysis of AHP, the importance of the function of the tachograph is sorted. It is found that users pay more attention to the safety function of the tachograph. The fatigue driving early warning function accounts for the highest weight, followed by ADAS driving assistance function. When designing related products, it should be put in the first place. In this paper, the analytic hierarchy process (AHP) is applied to provide a quantitative decision-making basis for product function positioning, which makes the design process more reasonable and efficient. It is convenient for designers to design products that are more in line with the needs of users, cater to the new social trends and have more competitive advantages.

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