Research on Innovative Design of Towable Caravans Integrating Kano-AHP and TRIZ Theories

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***Abstract*—The caravan industry in China is facing significant challenges, primarily because the mode of caravan travel is relatively niche within the country and the industry as a whole has had a slow start. This has ultimately resulted in a mismatch between the design aesthetics of caravans and the preferences of Chinese consumers. Based on the foundation of understanding user preferences, this study proposes a new design methodology that integrates the Kano model, the Analytic Hierarchy Process (AHP), and TRIZ theory to align with the preferences of Chinese users. Initially, a Kano model is constructed based on the suggestions from experts and users to categorize user needs. Subsequently, the AHP method is employed to reclassify the key needs identified in the Kano model, establish judgment matrices, and develop a scoring system to provide a scientific basis for design decisions. Finally, TRIZ theory is applied to address potential physical and technical contradictions encountered during the design process, thereby developing practical and aesthetically pleasing caravan design solutions.**

Keywords—Kano model; towed caravans; exterior design; Analytic Hierarchy Process (AHP); TRIZ theory

I. Introduction

Today, with the development of globalization, the recreational vehicle (RV) industry has seen widespread proliferation in both developed and developing countries [1]. RV products are primarily categorized into two types: self-propelled RVs and towable caravans, distinguished by their mode of propulsion. Towable caravans are towed behind a vehicle, relying on the towing vehicle for power, while self-propelled RVs possess their own propulsion systems. Nonetheless, the design approach of towable recreational vehicles (RVs) in the Chinese market is characterized by its conservatism, markedly lacking in uniqueness and innovation. This prevalent design philosophy, primarily focused on replicating foreign models, does not effectively accommodate China's unique national conditions and the behavioral patterns of its users. Consequently, there is a paramount need for dedicated research and development efforts aimed at producing indigenous RVs, specifically engineered to fulfill the distinct needs of local consumers [2].This is primarily due to a lack of comprehensive qualitative analysis of consumer preferences during the design process, resulting in a failure to meet consumer needs. In the gathering of Chinese literature, research on the development of RV products primarily revolves around consumer demands, with keywords such as humanization, aesthetics, and innovation featuring prominently in the Chinese literature [3-5]. Therefore, it is necessary to strengthen the design process and prioritize the product characteristics so that the user needs are correctly weighted [6].User characteristic analysis emerges as a pivotal step within the realms of product design and enhancement, facilitating a profound comprehension of user necessities and fostering an augmentation in product contentment. At present, the Kano model, AHP (Analytic Hierarchy Process) analysis method, and TRIZ (Theory of Inventive Problem Solving) theory stand as efficacious instruments for user analysis and the application of engineering technologies, having been substantively implemented across a diversity of domains.

Kano model was proposed by the Japanese scholar Noriaki Kano in 1984 [7], the model is utilized to assess the impact of product or service attributes on customer satisfaction, It categorizes user needs into distinct classifications to better meet customer expectations, encompassing the following five product attributes:(1) Must-be,(2) One-dimensional,(3) Attractive,(4) Indifferent, and (5) Reverse. By constructing specific product quality elements, the quantification analysis of user needs in the product design and development process is addressed. It captures the nonlinear relationship between product performance and customer satisfaction [8]. In their study on ceramic souvenirs, Tama [9] employed a combination of Kansei Engineering for extracting design-related words and the Kano Model for statistical analysis. The study's findings highlighted the significant role of visual characteristics in consumer satisfaction. Jin [10] et al. combined the Kano model with Kansei Engineering to enhance product emotional design, using customer reviews to identify and prioritize key features. Their approach, applied to smartphone design, provides insights for aligning product development with customer emotional needs.

The Analytic Hierarchy Process (AHP) is a multi-level decision-making method established by American operations researcher T.L.Saaty [11].According to their respective objectives, the problem is decomposed into different levels, and factors are weighed at each level to ensure the independence and scientific rigor of the final outcome. The purpose is to assist decision-makers in systematically balancing and making decisions in complex decision environments. They decomposed the elements determining user requirements into levels such as objectives, criteria, and solutions, conducting both qualitative and quantitative analyses to derive high-quality solutions. In product development and design, the Analytic Hierarchy Process (AHP) can assist in precisely selecting the final design factors. These design factors are typically critical elements affecting product performance, cost, quality, and other aspects, playing a decisive role in the overall performance and competitiveness of the product.

Varolgüneş [12] et al. utilized QFD and AHP in their research, focusing on customer-driven design for thermal hotel structures. Their approach, validated through stakeholder participation, effectively translated complex customer requirements into specific design elements. Han [13] et al. used a survey to delineate design elements for medical products in elderly households, applying an AHP model for systematic prioritization. This research enhances medical product design evaluation for elderly usage. Zhang [14] et al. derived cultural genes from Southern Dynasties' stone carvings using memetics. They created a design element genetic map, applied AHP for factor weighting, and analyzed user needs to develop cultural and creative product designs. Liu [15] et al. used AHP to improve medical product design for rhinitis, prioritizing design elements and reducing decision risks. Their approach, combining expert input and indicator ranking, streamlines development for rhinitis medical products.

The Kano Model enables a multi-dimensional assessment of product features, complementing the AHP model, which lacks a clear analysis of the urgency in improving a single evaluation factor. The AHP model determined the relative importance of customers' demands. It is helpful in improving the design efficiency and enriching the product types [16].However, the results derived from integrating the Kano model with the Analytic Hierarchy Process do not address how to conduct design practices, thus necessitating the introduction of TRIZ theory. TRIZ, a theory of inventive problem-solving, was developed by Altshuler and his team after analyzing 2.5 million patents worldwide. It provides a logical approach to developing creativity for innovation and inventive problem solving [17]. Altshuller identified 39 technical parameters and 40 inventive principles that can be used to eliminate technical contradictions [18]. Any technological conflict can be described by a pair of parameters, and for every such described technological conflict, there exists an innovative solution. The methods for solving these are summarized and distilled into 40 inventive principles, Caligiana [19] et al. integrated QFD and TRIZ theories to develop a design method for direct open moulds. This approach included six-question analysis, assessment matrices, and morphological matrix analysis. The QFD analysis results defined product requirements and architecture, which were then used in TRIZ analysis to complete the design process. Gao[20] et al. applied the TRIZ theory, incorporating techniques like the Conflict Matrix, Substance Field Analysis, Standard Solutions, and Effects, to analyze and redesign infusion systems. Their work illustrates the broad utility of TRIZ theory in medical device development.

In previous literature studies, the Kano model, AHP (Analytic Hierarchy Process) analysis method, and TRIZ theory have been successfully applied by scholars to address a variety of practical problems, demonstrating their substantial utility and efficacy. To date, no literature has employed this integrated approach in the development of towable caravans, hence, this research carries a unique innovative value in its methodological application. In the process of the study, through the Kano model, user requirements are meticulously categorized, and then optimized through the Analytic Hierarchy Process to ensure that the design solutions comprehensively meet the diverse needs of users. In the face of engineering technical contradictions, TRIZ theory is applied for resolution. Three design proposals are developed using computer models and evaluated to determine a final design solution. We collaborated with Chinese RV companies and conducted a six-month exploratory study within the Chinese RV industry, recording real-time data in the engineering development of towed RVs. This data provided a valuable basis for further optimizing the design solutions.

The contributions of this paper are as follows:

A towed caravans evaluation model based on Kano-AHP and TRIZ theories is proposed.

A novel evaluation system for the design field of Chinese towed caravans is provided, integrating methods for addressing engineering technical problems and offering strong support for product development.

Through computer modeling techniques, three towed caravans design proposals are developed. Based on the actual requirements of RV enterprises, these three designs were evaluated and one design that best meets market demands and production realities was selected.

The structure of the remainder of this paper is as follows: Section
II will provide a detailed description of the preliminary work a
nd experimental process of the paper and explain the process of handling and categorizing user requirements through the Kano model. Section III will optimize the comprehensive evaluation of towed recreational vehicles according to the results of the Kano model using the Analytic Hierarchy Process. Section IV will employ TRIZ theory for technical analysis based on the results of the needs and propose the final design solution. Section V will analyze and discuss the final design solution, identifying the optimal solution by comparing the strengths and weaknesses of different proposals and discussing its feasibility in production and market prospects. Section VI will summarize the research content and outcomes of the paper, extracting the innovative points and contributions of the study, and looking forward to future research directions and application prospects, providing a beneficial reference for the sustained development of the Chinese RV market.

II. User Demand Analysis Based on the Kano Model

A. Research Process

Thorough discussions and careful analysis by the design team, we defined a research direction focused on serving Chinese users and developing trailer campers. Following this, we established a complete and targeted research framework. The entire experimental design process is illustrated in Fig. 1.

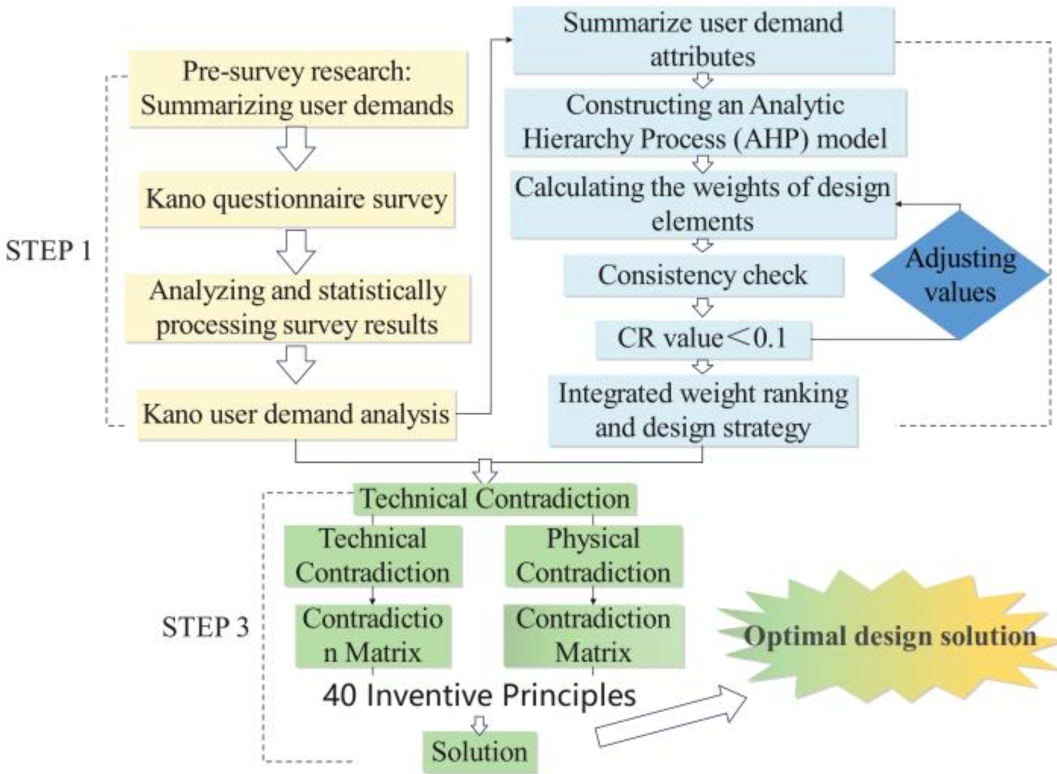

Fig. 1. Experimental design flowchart.

B. *User Demand Segmentation*

More and more working-class people are joining this travelling [21], the focus of user demands should not be on the elite class. Wu [22] et al. found that Chinese RV users are characterized by their deep love of travel, pursuit of freedom, comfort, personalization, and a passion for nature. Under the guidance of seasoned professionals, the design team defined the target audience for towable RVs as middle-aged and older adults aged between 50 and 60 years. This demographic has significant purchasing power and places particular emphasis on the safety and comfort of RVs, as well as the desire to enjoy RV travels with their families. After identifying the target users, it was necessary to further refine their needs. After identifying the target user groups, it is necessary to further refine their needs. Cost-effectiveness and family-centric considerations have become the guiding principles for our questionnaire data collection. The primary concerns of users are centered on the qualifications of towing vehicles and the conditions for driving. Thus, it is advisable to focus research on medium and small-sized trailers. Additionally, our design team conducted thorough discussions with five RV owners, among whom two own towable RVs, to collect insights. These owners shared their principal considerations when purchasing RVs, complemented by the recommendations of a design professor. Based on the basic functions of towable RVs, user needs were categorized into primary needs: functionality, aesthetics, and materials. These primary needs laid the foundation for further work, facilitating the breakdown and refinement into specific secondary needs, which were organized and summarized in Table I.

TABLE I. USER DEMAND SEGMENTATION

Primary Needs	Secondary Needs
Functional Layer	Ventilation Smart Lock Safety Alarm Off-road Capability Space Expansion Sunshade Easy Operation Viewing Space Vehicle Monitoring
Aesthetic Layer	Decals Minimalist Design Light-colored Body Streamlined Appearance Biomimetic Form Decorative Lights Rugged Structure Rounded Feel
Material Layer	High Load-bearing Chassis Additional Screen Door Lightweight Materials Integrated Windows Eco-friendly Materials Clean Energy Customized Materials

C. Questionnaire Design and Analysis

In Tables II and III, the design team conducted a Kano questionnaire survey comprising 85 responses. To ensure the accuracy and reliability of the survey outcomes, we distributed 41 paper questionnaires individually at the Trailer Camping Exhibition. Additionally, we collected 44 questionnaires through an online platform. This combined online and offline approach allowed us to comprehensively cover the target user group and gather diverse data. To evaluate the reliability and effectiveness of the questionnaire, the SPSS 27 software was employed to conduct a reliability test on the online survey [23]. The results indicated a Cronbach's Alpha coefficient of 0.817 for the online questionnaire, demonstrating a high level of reliability and validity for our questionnaire.

If the appearance design of the trailer has the following characteristics, what is your attitude?

TABLE II. KANO POSITIVE QUESTIONNAIRE ON TRAILER DESIGN

Characteristics	Like	Must-Be	Neutral	Live-with	Dislike
Ventilation	5	4	3	2	1
Decals	5	4	3	2	1
Lightweight Materials	5	4	3	2	1

If the appearance design of the trailer does not have the following characteristics, what is your attitude?

TABLE III. KANO REVERSE QUESTIONNAIRE ON TRAILER DESIGN

Characteristics	Like	Must-Be	Neutral	Live-with	Dislike
Ventilation	5	4	3	2	1
Decals	5	4	3	2	1
Lightweight Materials	5	4	3	2	1

D. User Satisfaction Analysis

After eliminating invalid questionnaires, a significant number of valid questionnaires were successfully recovered. Based on these questionnaires' results, we recorded the frequency of positive and negative outcomes into the Kano result evaluation form, the evaluation table and results were tabulated for each attribute [24], as presented in Table V. The user's feedback on different requirements is classified, and these requirements are divided into different attribute types accordingly. Attractive (A) means that when the product or service does not provide this function, there is no negative impact on consumer satisfaction; however, when this feature is provided, consumer satisfaction increases significantly. One-dimensional (O) means that when the product or service provides this function, consumer satisfaction will increase ; when this function is not provided, consumer satisfaction will show a downward trend. Indifferent (I) means that no matter whether the product or service provides this function, it has little effect on consumer satisfaction. Must-be (M) means that when the product or service provides this function, it has no effect on user satisfaction; however, when this function is not provided, user satisfaction will show a downward trend. Reverse(R) means that when a product or service provides this function, it will cause user dissatisfaction; when this function is not provided, the user's satisfaction will be improved, and the quality Q represents the result is questionable. Kano model requirement analysis is presented in Table IV.

TABLE IV. KANO MODEL DEMAND MATRIX

User Attitude		Inverse Problem				
		Like	Must-Be	Neutral	Live-with	Dislike
Forward Problem	Like	Q	A	A	A	O
	Must-Be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live-with	R	I	I	I	M
	Dislike	R	I	R	R	Q

We use the Better-Worse coefficient analysis method to calculate the satisfaction coefficient of each demand. The Better-Worse coefficient analysis method is used to obtain each functional requirement index in t Kano model, and calculate the user's satisfaction and dissatisfaction, see Formula (1) (2).The calculation result of the Better coefficient is 0 ~ 1, and the closer the Better coefficient is to 1, it means that providing this function is sensitive to the user 's satisfaction. The calculation result of the Worse coefficient is -1 ~ 0, and the closer it is to -1, the more sensitive it is to the user 's dissatisfaction [25].According to the results obtained, the Kano model results are analyzed, see Table V, and the quadrant diagram is drawn (see Fig. 2).

$$Better = \frac{A+O}{A+O+M+I} \tag{1}$$

$$Worse = (-1) * \frac{O+M}{A+O+M+I} \tag{2}$$

TABLE V. ANALYSIS OF KANO MODEL RESULTS

Demand items	M	O	A	I	R	Q	Attribute	Better	Worse
Ventilation	18	46	12	9	0	0	O	0.682	-0.753
Off-road Capability	9	41	20	15	0	0	O	0.718	-0.588
Easy Operation	7	44	16	18	0	0	O	0.75	-0.6
Minimalist Design	14	57	8	6	0	0	O	0.765	-0.835
Light-colored Body	9	38	16	17	5	0	O	0.675	-0.588
Rugged Structure	9	40	7	23	6	0	O	0.595	-0.620
High Load-bearing Chassis	6	48	23	8	0	0	O	0.835	-0.635

Clean Energy	11	39	15	17	3	0	O	0.659	-0.61
Safety Alarm	47	13	9	16	0	0	M	0.259	-0.706
Biomimetic Form	36	15	14	19	0	1	M	0.345	-0.607
Additional Screen Door	37	20	18	6	4	0	M	0.469	-0.703
Eco-friendly Materials	42	20	8	14	0	1	M	0.333	-0.738
Space Expansion	6	23	43	11	2	0	A	0.795	-0.349
Sunshade	19	21	33	12	0	0	A	0.635	-0.471
Viewing Space	8	14	43	16	3	1	A	0.704	-0.272
Vehicle Monitoring	7	12	35	31	0	0	A	0.553	-0.224
Decals	5	16	42	21	1	0	A	0.690	-0.25
Lightweight Materials	24	12	35	14	0	0	A	0.553	-0.429
Smart Lock	12	9	23	39	2	0	I	0.386	-0.253
Streamlined Appearance	11	17	20	31	6	0	I	0.468	-0.354
Decorative Lights	10	13	19	41	2	0	I	0.381	-0.274
Rounded Feel	4	15	11	31	24	0	I	0.426	-0.311
Integrated Windows	21	17	6	41	0	0	I	0.27	-0.447
Customized Materials	7	4	15	52	7	0	I	0.244	-0.141

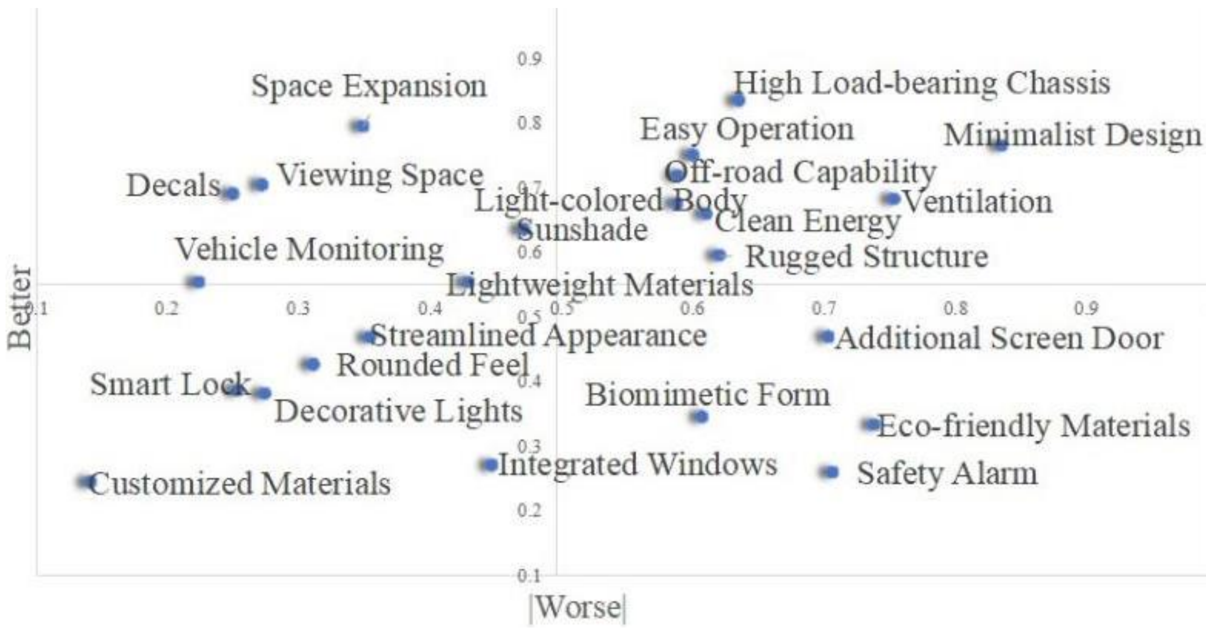

Fig. 2. Better-Worse four quadrant scatter plot.

III. BUILD USER DEMAND HIERARCHY ANALYSIS MODEL

Incorporating the experimental outcomes from the Kano model, the inclusion of 'Attractive (A)' demands within the AHP framework contributes significantly to refining the prioritization and comprehensive evaluation processes of identified user needs. Quantifying the expertise of professionals and conducting comprehensive assessments of various indicators from diverse perspectives and levels further facilitates a more thorough and comprehensive understanding of their relative significance.

A. *Constructing a User Needs Hierarchy Analysis Model*

Filling the comparison matrix involves comparing every element from the set of criteria to itself through a pairwise comparison [26], thereby assisting the decision maker in setting preferences to make the best selection possible [27]. The model is divided into the target layer, criterion layer [13], and Sub-criterion layer. Finally, the user demand hierarchy model is constructed, as shown in Fig. 3.

- Target layer: Design Concept of a Towable Trailer Camper (X).
- Criteria layer: Space Expansion(A),Sunshade(B), Decals(C),Lightweight Materials(D),Vehicle Monitoring(E) and Viewing Space(F).
- Sub-criterion layer: Side retractable expansion compartment for vehicles (A_1) , Rear retractable

expansion compartment for vehicles (A_2), Roof lift-expandable compartment for vehicles (A_3), Hybrid Expansion Module Mode (A_4), Portable Assembly (B_1), Integrated (B_2), Retractable (B_3), PVC color decal (C_1), Paint spray art (C_2), Aluminum plate (D_1), Fiber reinforced plastics (D_2), Carbon fiber (D_3), Covert RV surveillance (E_1), Overt RV surveillance (E_2), Rooftop Terrace (F_1), Indoor Viewing (F_2), Viewing Tent (F_3).

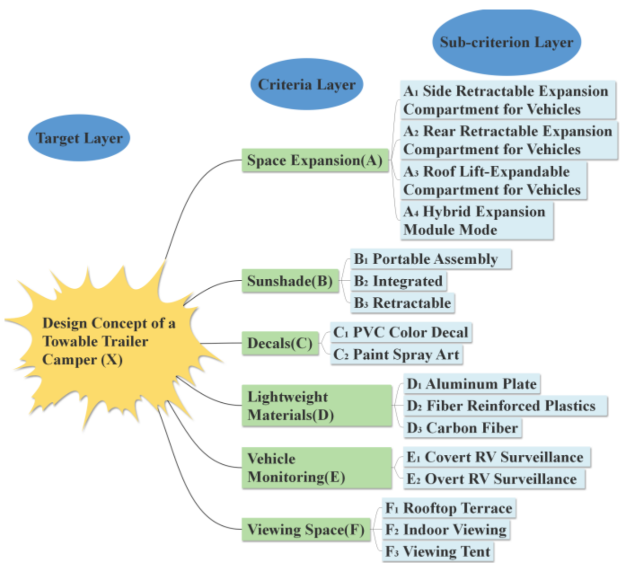

Fig. 3. User needs hierarchy analysis model.

B. Calculate the Weights of Design Elements

In the Analytic Hierarchy Process (AHP), to avoid a singular qualitative outcome, elements are typically compared pairwise to determine the relative importance between them. The judgment matrix reflects the importance of each variable in the hierarchical structure and forms the core component of this method. The judgment matrix was set up with the adoption of the 'ninth level method' [28].The definition of the 1-9 ratio scale is outlined in the Table VI.

TABLE VI. SCALE OF JUDGMENT MATRIX IMPORTANCE INDICATORS

Scale	Level of importance	Implication
1	Equally important	Indicator a and indicator b are equally important
3	Slightly important	Indicator a is marginally more important than indicator b
5	Significantly important	Indicator a is significantly more important than indicator b
7	Very important	Indicator a is very important compared to indicator b
9	Absolutely important	Indicator a is more important than indicator b
2,4,6,8	Inversion comparison	Take the middle part

To ensure the objectivity and rigor of the evaluation process, this experiment involved 4 RV styling development engineers and 2 product design professors in the decision-making process. Based on the ratio scale in Table VI, this study conducted pairwise comparisons of various parameters to precisely assess their relative importance. Each judgment matrix is presented in an n×n dimension, where n represents the number of parameters. The element bij in the matrix indicates the importance of parameter bi relative to parameter bj, as seen in Formula (3).

The judgment matrix Y is presented in Equation (3):

$$Y = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{bmatrix} \tag{3}$$

During the decision-making process, six experts were organized to discuss in meetings and fill out questionnaires anonymously. The results of the collected questionnaires were then fed back to the experts for result analysis, and based on the results of the previous round, questionnaires were distributed again. This cycle was repeated until the final consensus of the experts was reached [29-31]. Some of the questionnaires are shown in Fig. 4, and the consolidated matrix is seen in Formula (4).

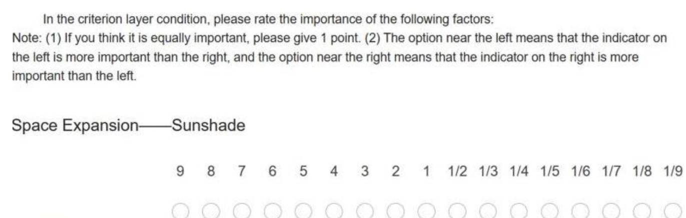

Fig. 4. Expert questionnaire (part).

The final judgment matrix X is given in the Formula (4):

$$X = \begin{bmatrix} 1 & 2 & \dots & 1/3 \\ 1/2 & 1 & \dots & 1/5 \\ \dots & \dots & \dots & \dots \\ 3 & 5 & \dots & 1 \end{bmatrix} \tag{4}$$

Normalize the judgment matrix according to Formula (5):

$$\overline{b_{ij}} = \frac{b_{ij}}{\sum_{k=1}^{n} b_{ki}}, i, j = 1, 2, \dots, n \tag{5}$$

Calculate the average value of each parameter's normalized row in the judgment matrix according to Formula (6):

$$W_i = \sum_{j=1}^{n} \frac{\overline{b_{ij}}}{n}, i = 1, 2, \dots, n \tag{6}$$

Tables VII display the assessment results for each proposal:

TABLE VII. TARGET-LEVEL JUDGMENT MATRIX AND WEIGHTS

Target layer	Criteria layer	Weight	Rank	Sub-criterion layer	Weight	Rank
X	A	0.142	3	A_1	0.345	2
				A_2	0.062	4
				A_3	0.146	3
				A_4	0.447	1
	B	0.118	4	B_1	0.110	3
				B_2	0.309	2
				B_3	0.581	1
	C	0.049	6	C_1	0.750	1
				C_2	0.250	2
	D	0.253	2	D_1	0.083	3
				D_2	0.724	1
				D_3	0.193	2
	E	0.055	5	E_1	0.667	1
				E_2	0.333	2
	F	0.383	1	F_1	0.655	1
				F_2	0.265	2
				F_3	0.080	3

C. Consistency Check

In order to ensure consistency in evaluators' relative judgment logic throughout the evaluation process, it's necessary to conduct a consistency check on the judgment matrix. Calculate the consistency ratio based on the order of 'n' in the judgment matrix. In the consistency check, λ max is used as a significant validation parameter for the consistency ratio. Saaty validated that for a positive reciprocal matrix, λ max is always greater than or equal to 'n'.If the CR < 0.10, the matrix is considered consistent, and the derived weights are then reliable for supporting decision-making [6].If the CR value exceeds 0.1, it requires experts to recompare various parameters in the judgment matrix until the CR value falls within an acceptable range. Generally, a smaller CR value indicates better consistency in the judgment matrix.

The calculation process is as follows:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)i}{nWi} \tag{7}$$

λ max represents the maximum eigenvalue, and 'n' stands for the order of the judgment matrix.

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{8}$$

CI represents the Consistency Index of the judgment matrix.

$$CR = \frac{CI}{RI} \tag{9}$$

RI represents the Random Index for Average Random Consistency, and CR stands for Consistency Ratio. The values for the Average Random Consistency Index are provided in Table VIII.

The calculated CR values from Table VII were subjected to a consistency check, indicating that all the judging matrices passed the consistency check and that the sum of the weights satisfying the condition should be equal to one [32].The experimental results are feasible, as shown in Table IX.

D. Comprehensive Weight Ranking

Based on the weight values from Table VII, the determination of the sub-criteria layer's respective indicator weights towards the combined weight vector of the target layer is established, as detailed in Table X. Within the criteria layer, the ranking of weight values is as follows: F > D > A>B>E >C. Based on the prioritization of weights, the design of innovative scenic viewing spaces requires special attention. Next, the inclusion of multifunctional vehicle monitoring devices should be considered. At the same time, the creation of visual appeal and first impressions should not be overlooked, as people often focus their attention on objects they encounter for the first time. The vehicle's decal decorations and the style of the model also impact consumers' purchasing decisions, thus their roles need to be considered in the design process. At the level of sub-criteria, the ranking of comprehensive weight values is as follows: $F_1>D_2>F_2>B_3>A_4>A_1>D_3>C_1>E_1>B_2>F_3>D_1>A_3>E_2>B_1>C_2>A_2$, Experimental results indicate that in the Chinese consumer market, sensitivity and awareness of unique design elements, such as rooftop terraces, are relatively high.

TABLE VIII. AVERAGE RANDOM CONSISTENCY INDEX

Matrix rank	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

TABLE IX. CONSISTENCY TEST RESULTS

F	X	A	B	C	D	E	F
λ max	6.475	4.124	3.004	2	3.066	2	3.033
CI	0.095	0.041	0.002	0	0.033	0	0.016
RI	1.260	0.890	0.520	0	0.520	0	0.520
CR	0.075	0.046	0.004	\	0.063	\	0.031

TABLE X. COMPREHENSIVE WEIGHT RANKING

Sub-criterion layer	Weight	Overall weight	Overall Rank
A_1	0.345	0.0490	6
A_2	0.062	0.0088	17
A_3	0.146	0.0207	13
A_4	0.447	0.0634	5
B_1	0.110	0.0130	15
B_2	0.309	0.0364	10
B_3	0.581	0.0686	4
C_1	0.750	0.0368	8
C_2	0.250	0.0123	16
D_1	0.083	0.0210	12
D_2	0.724	0.1832	2
D_3	0.193	0.0488	7
E_1	0.667	0.0367	9
E_2	0.333	0.0183	14
F_1	0.655	0.2509	1
F_2	0.265	0.1015	3
F_3	0.080	0.0306	11

IV. APPLICATION OF EXTERIOR DESIGN IN TOWED CARAVANS

Before conducting the TRIZ theoretical analysis, we conducted an in-depth examination of the legal restrictions stipulated in the "Road Traffic Safety Law of the People's Republic of China" regarding towable caravan, to gain a comprehensive understanding of the operational rules and limitations for such vehicles within the legal framework of our country. Based on the "Better-Worse" ranking of the Kano model and the weight ranking of the Analytic Hierarchy Process (AHP), caravan development engineers have identified the main contradictions faced in practical applications. By analyzing the types of contradictions according to TRIZ theory and consulting the corresponding contradiction matrix for recommended inventive principles, the conflict analysis and resolution principles are presented in the Table XI-XII.

TABLE XI. PHYSICAL CONTRADICTION

Conflict Number	Conflict	Type of Contradiction	Separation Mode	Inventive Principle
01	Clean Energy (solar panels)-Rooftop Terrace	Physical Contradiction	Space	1，2，3，4，7，13，17，24，26，30

Clean energy is supplied through solar energy storage to reduce energy consumption and achieve sustainability and environmental protection. However, the presence of solar energy storage systems limits the available area of the rooftop leisure area. To address the physical contradiction between clean energy (solar panels) and rooftop terraces, the principle of spatial separation is applied to resolve the conflict between solar panels and rooftop terraces in physical space. This conflict arises from two different properties exhibited by the same material under the same conditions. Methods such as segmentation (Principle 1) and multi-dimensional operation (Principle 17) are used for problem-solving. Specifically, the rooftop is divided into two independent areas: one area for solar energy storage and another area as a rest area for users. Through this division, an innovative application of rooftop space is achieved.

TABLE XII. TECHNICAL CONTRADICTION

Conflict Number	Conflict	Type of Contradiction	Improved Parameters	Deteriorating Parameter	Inventive Principle
01	Lightweight Materials-Side retractable expansion compartmet for vehicles	Technical Contradiction	No.7 Volume of moving object	No.1 Weight of moving object	2,26, 29,40
02	Easy Operation-Retractable		NO.35 Adaptability	NO.33 Weight of moving object	15,34, 1,16
03	Easy Operation-Overt RV surveillance				

To address the technical contradiction between lightweight materials and the vehicle's side expansion chamber, the extraction principle (Principle 2) and the composite material principle (Principle 40) are primarily employed for resolution. The use of retractable vehicle side expansion compartments effectively increases the usability of space while also enhancing user experience. The expansion chamber is made of aluminum alloy to increase its stability. For the common technical contradiction between simplicity of operation and intelligent retractable awnings, overt RV surveillance, the principles of elimination and recovery (Principle 34) and the dynamic principle (Principle 15) are mainly used for resolution. Discarding the superfluous functions and parts simplifies operations under a variety of functionalities, dividing user operations into one-button start and mobile phone operations, categorizing the use functions accordingly.

V. RESULTS AND DISCUSSION

A. *Design Outcomes of Styling*

The design team analyzed the results of the evaluation of various indicators. In terms of space expansion, expanding from the sides was found to be more in line with user needs and corporate development objectives. It is necessary to consider the strength, durability, and load-bearing capacity of materials. Using fiberglass for the outer shell enhances robustness. For the expansion cabin, an internal framework made of aluminum alloy is employed to reinforce, improving the trailer's stability and durability, thus ensuring the safety of users. A simple and easy-to-deploy square awning tent is used for the sunshade, operated in a roll-up fashion for user convenience. Camping sites are generally chosen in the wild, so the design of vehicle monitoring must ensure no blind spots in the field of view, considering the synchronous viewing of sound and image to help users directly obtain external information and ensure their safety. The development of the rooftop terrace received the highest weight value in the AHP evaluation, with the vehicle's top development based on the segmentation principle of TRIZ theory. Similarly, the rooftop needs to have load-bearing capacity to withstand impacts and knocks. In the course of in-depth communication with enterprises, it was understood that Chinese users have a relatively conservative preference for the appearance of trailers. Therefore, we will take the style of trailers popular in the Chinese market as a reference for research and innovative design. Additionally, Chinese laws have strict management requirements for the modification of trailer vehicle models, considering the safety of pedestrians and drivers. In terms of material selection, we must adhere to international standards to ensure product compliance and avoid potential risks associated with vehicle launch. For example, in the choice of vehicle lights, we referred to the lamp models provided by suppliers to RV enterprises, and the design of the lamp assembly layout was based on China's traffic management legislation. Although aesthetics is an element of interesting value that provides value to the product [33], it is necessary to consider that large-scale car body decals would incur high costs. In the decal design, we fully considered the three elements of fashion, beauty, and simplicity, and determined the final decal style.

The first design proposal was the original plan developed by the team, see Fig. 5. Simultaneously, based on the preliminary concept, the overall dimensions of the vehicle were annotated, and a layout design of the interior space was drawn up based on these dimensions. This serves as an important reference for our exterior design, as seen in Fig. 6. Anti-roll frames were equipped on both sides to prevent the danger of users rolling off while resting (see Fig. 7).

Fig. 5. The first design scheme.

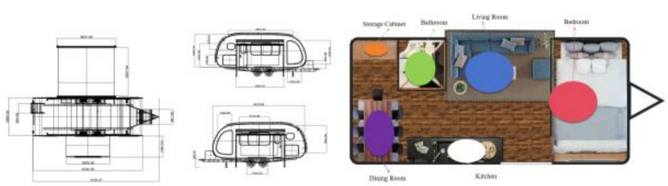

Fig. 6. Internal structure and dimensioning diagram.

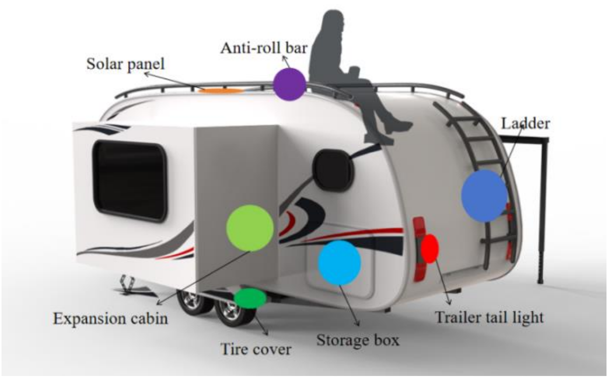

Fig. 7. The first design scheme function display diagram.

The second design proposal (see Fig. 8 and 9). The roof adopts a folding structure, utilizing the principle of segmentation. The position of the solar panels can be leaned against after the top of the towable caravans is folded. This design has a smaller area of solar panels, prioritizing services for user leisure. Based on the first proposal, slight adjustments were made to the exterior design; the body's curvature was reduced to expand the area of the windows, facilitating users in enjoying the scenery, surveillance cameras with no dead spots can play a deterrent role.

Fig. 8. The second scheme design.

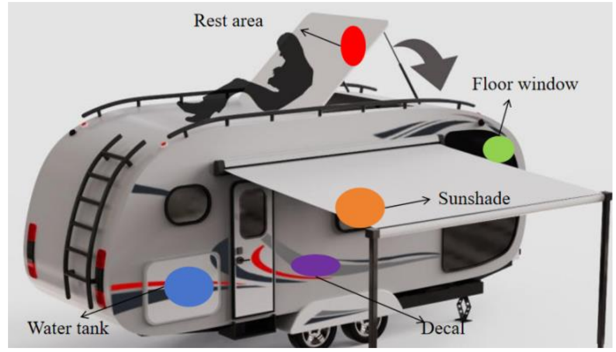

Fig. 9. The Second design scheme function display diagram.

The third design proposal (see Fig. 10), places the solar panels on an elevatable roof, dividing the roof space into two parts. When the ceiling is raised, it can be used as a terrace, providing users with more activity space. As seen in Fig. 11, the solar panels can continue to absorb energy.

Fig. 10. The third scheme design.

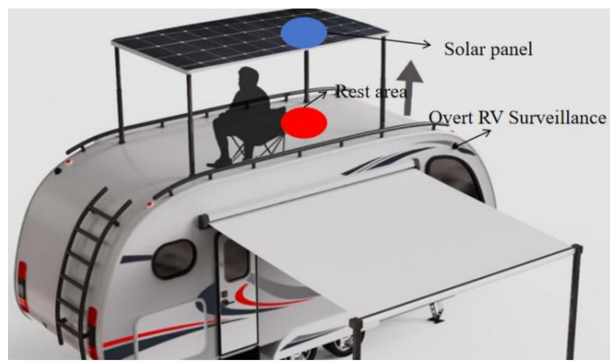

Fig. 11. The Third design scheme function display diagram.

B. *Discussion of Practical Development Issues*

During the finalization phase of the design proposals, an in-depth discussion was conducted within the group. The first design proposal had clear shortcomings in terms of user experience, with its activity space being limited to half, obviously failing to meet the practical needs of actual users. This proposal also lacked innovation, making it difficult to stand out in the market, and was considered as a basis for subsequent improvements. Although the folding structure and floor-to-ceiling window design of the second proposal were creative, offering more space for user activities compared to the first proposal, the space for the rooftop solar panels was too small to be practically operational. The third proposal, with its elevatable terrace design, provided users with a much broader activity space, enhancing the user experience. The simple terrace design effectively resolved the issue of potential decreases in user willingness to use due to high appearance costs. Considering its practicality, innovation, and cost-effectiveness, the third proposal holds significant market potential and user appeal, warranting further investment in the production phase.

To ensure driving safety, the manufacturing process of the towable caravans needs to rigorously integrate multiple intelligent systems, including real-time display of braking status, driving balance control, tire pressure monitoring, reversing image, intelligent alarm, and smart lock systems. The integration of these systems aims to provide users with real-time information and services, necessitating the development of a dedicated mobile interaction system for intelligent management and control. However, it is noteworthy that the actual production process of the towable caravans is exceedingly complex, involving numerous technical details and process requirements. Therefore, decisions made in the preliminary phase will directly impact the smooth progression of the subsequent production process and the quality and performance of the final product.

VI. Conclusions

This study, based on the capture of user data, optimizes the Analytic Hierarchy Process (AHP) through the Kano model, scientifically calculates the weight values of each element, and thus makes an accurate assessment of the importance of each element. This not only provides solid theoretical support for the design of towable caravans but also ensures the high specificity and practicality of the design scheme. During the research process, we actively cooperated with caravan companies, fully drawing on their rich market experience, conducted in-depth analyses of contradictions that arose during the design process with the aid of TRIZ theory, and proposed viable solutions. On this basis, three trailer caravan schemes were designed, and through thorough discussion by team members, a design scheme that fits the principles of practical development was selected.

However, there are some shortcomings in this study. First, the development cycle of towable caravans is long and involves many factors. Although a towable caravan shape that meets the needs of Chinese consumers has been designed, it still needs to be continuously adjusted and optimized according to actual production situations. Second, the finalization of the scheme is still limited by the decision-making of the R&D team and does not fully consider the preference differences of consumers towards the design scheme. Lastly, the caravan industry in China started later, and the trailer caravan market is relatively niche. Enterprises are relatively conservative in innovation, which also limits our bold attempts in scheme design.

In the future, we will continue to focus on the development process of towable caravans in China, recording and solving problems encountered during development. At the same time, we plan to further apply this theoretical framework to explore the interior design of trailer caravans, with the aim of meeting user needs while enhancing the economic benefits of enterprises. By continuously optimizing design schemes and exploring new design ideas, we will vigorously promote the sustained and healthy development of China's caravan industry.

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