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Construction of a High-End Experience Evaluation System for Passenger Vehicles Based on Multi-Scenario Human Factors Experiments

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Abstract

China's passenger vehicle industry is currently shifting from scale expansion to value-based competition, with premiumization, experiential design, and scenario integration emerging as key pathways for domestic brands to break through the pricing bottleneck. Traditional evaluation systems emphasize hardware specifications while overlooking user perception and adaptation to high-end scenarios, making it difficult to quantify the true experiential value of ultra-luxury vehicles. This study focuses on five premium segments—sedans, SUVs, MPVs, off-road vehicles, and sports cars—and conducts empirical research in major consumer cities. By establishing standardized human factors experimental environments, we collect multidimensional data on behavior, physiological responses, and subjective evaluations. Based on survey data, integrating human factors experiments with fuzzy comprehensive evaluation, we develop a multi-level evaluation framework for premium experiences, assigning weights and validating effectiveness. Empirical results show that premium experience stems not merely from hardware accumulation but from the synergistic combination of spatial immersion, interactive ritualism, scenario adaptability, sensory comfort, and exclusive services, with significant differences in experiential weight across segments. The proposed evaluation system provides scientific support for premium vehicle development, experience enhancement, and the establishment of industry standards.

Keywords

User perception; human factors experiment; fuzzy comprehensive evaluation; weight assignment.

1. Introduction

As the automotive industry transitions toward high-quality development, consumer demand has evolved from a basic need for transportation to a premium pursuit of quality experiences, identity recognition, and scenario-specific exclusivity. Domestic brands are accelerating their entry into the segment above 500,000 yuan, shifting competition from hardware specifications to holistic experiential value. Authorities such as the Ministry of Industry and Information Technology and the China Automotive Technology and Research Center have explicitly called for establishing localized evaluation standards for high-end user experiences, driving the industry's transformation from "parameter-driven manufacturing" to "experience-driven manufacturing" [1].However, existing evaluation systems suffer from four key shortcomings: first, dimensional homogeneity—overemphasis on quantifiable metrics while neglecting soft experiences such as sensory immersion and contextual ritual; second, insufficient standardization in methodology, relying heavily on subjective assessments without robust human factors data support; third, poor adaptability across sub-segments, failing to distinguish core pain points across sedans, SUVs, MPVs, off-road vehicles, and sports cars; fourth, a

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disconnect between research and product iteration, making it difficult to use experience data to inform forward development vehicle improvements. Meanwhile, high-end users tend to be highly educated, affluent, aesthetically discerning, and deeply scenario-oriented, seeking emotional resonance throughout the entire ownership journey beyond basic mobility functions. Traditional evaluation frameworks fail to meet their elevated perception expectations. Therefore, there is an urgent need to establish a quantitative, standardized, and scenario-based evaluation system grounded in scientific human factors experiments and user research, bridging the gap between user perception and R&D processes, and providing empirical support for industry standardization and the advancement of premium manufacturing.

Existing research primarily focuses on comfort and intelligent experiences in household vehicles, lacking a dedicated evaluation system for premium and ultra-luxury models, as well as empirical human factors data support. This study targets five major premium market segments, integrating human factors experiments, user interviews, and real-vehicle testing, and combines an improved Analytic Hierarchy Process with fuzzy comprehensive evaluation to establish a quantitative model of premium experience tailored to Chinese users' aesthetics and usage scenarios, effectively addressing the challenge of "immeasurability and non-quantifiability" of user experience. At the industrial level, the evaluation framework can be applied throughout the entire process of R&D, testing, and iteration, helping automakers accurately identify scenario-specific needs, avoid parameter-driven competition, and focus on resolving user perception pain points to achieve differentiated upgrades. It also supports domestic brands in benchmarking against ultra-luxury models, identifying weaknesses, building distinctive local experiential features, and enhancing their pricing power. At the industry level, this research provides empirical evidence for establishing standardized benchmarks in high-end automotive experience, promoting the normalization and development of evaluation systems, and supporting the upgrading of China's high-end manufacturing ecosystem.

2. Research Content

2.1. Core Theory

2.1.1. High-End User Experience

High-end passenger vehicle user experience refers to the comprehensive feedback generated by high-net-worth users throughout the entire process—from static vehicle evaluation and dynamic driving to scenario-based usage and service interaction—encompassing physiological perception, psychological cognition, and emotional resonance. It covers two major dimensions: objective behavioral experience and subjective emotional experience. Physiological perception involves multi-sensory aspects such as vision, hearing, touch, and smell; behavioral experience includes fluidity of human-machine interaction, control responsiveness, and efficiency in adapting to various scenarios; emotional experience focuses on a sense of ceremony, privacy, prestige, and scenario satisfaction. Together, these three elements form a multidimensional, multi-layered, and quantifiable holistic experience system.

2.1.2. High-end passenger vehicles

The high-end passenger vehicles referred to in this article are priced above 500,000 yuan, targeting affluent consumers and covering five segments: sedans, SUVs, MPVs, off-road vehicles, and sports cars. They include both traditional ultra-luxury fuel-powered models and premium intelligent new-energy vehicles. Their core value extends beyond basic transportation, focusing instead on delivering a multidimensional premium experience that emphasizes driving and riding rituals, sensory comfort, scenario adaptability, identity recognition, and exclusive services.

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2.1.3. Human Factors Experimentation Techniques

Automotive human factors experiments are empirical research techniques centered on human factors engineering, leveraging real-world vehicle scenarios and professional testing equipment to collect users' behavioral data, physiological indicators, and operational habits during vehicle use, thereby analyzing patterns of user perception and experiential needs. This paper employs standardized human factors experiments to transform abstract luxury experiences and perceptual preferences of high-end users into concrete, quantifiable, and analyzable objective data, providing empirical support for the development of evaluation frameworks.

2.1.4. Human-Machine-Environment System Theory

The human-machine-environment system theory forms the core foundation of automotive human factors research. Its fundamental premise is that passengers' overall in-vehicle experience is not determined by a single factor, but rather emerges as a comprehensive outcome shaped by continuous interaction and mutual influence among users, vehicles, and travel contexts. As the perceiving subject of experience, humans directly affect the threshold of experience through their physical characteristics, aesthetic preferences, and habitual operational patterns. The vehicle, as the material carrier of experience, establishes the physical baseline through its materials, craftsmanship, user interface, chassis tuning, and powertrain dynamics. Meanwhile, the environment—serving as the shaping context—constantly reshapes users' functional expectations and emotional projections, ranging from business commuting to family road trips, from unpaved roads to high-speed track driving. Grounded in this theoretical framework, this paper systematically integrates key indicators across these three dimensions into the evaluation system, aiming to ensure logical coherence and comprehensive coverage, thereby providing a solid theoretical foundation for subsequent empirical analysis.

2.2. Construction of a High-End Passenger Vehicle Experience Evaluation System

2.2.1. System Construction Principles

Based on the experiential characteristics of premium passenger vehicles and the requirements of empirical research, this paper establishes an evaluation system following six core principles, as shown in Table 1 below.

Table 1: Six Core Principles for Building the Evaluation System

Serial Number	Indicator	Instructions
1	Principle of Scientific Validity	Based on human factors engineering theory and empirical experimental data, indicators are selected and their effectiveness is validated through mathematical models to avoid subjective assumptions.
2	Principle of Segmentation and Differentiation	Tailor generic and specialized differentiated metrics to the distinct scenarios of five premium niche markets, aligning closely with the unique experience characteristics of each segment.
3	Principle of Full-Dimensional Coverage	Covering four dimensions—objective hardware experience, subjective perception experience, scenario adaptation experience, and emotional value experience—to achieve comprehensive coverage.
4	Quantifiable Principle	All indicators can be quantitatively evaluated through experimental data and mathematical calculations, avoiding vague qualitative measures.

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5	R&D Adaptation Principles	The indicator settings align with automakers' forward-looking R&D needs and can be directly converted into technical parameters for research and development.
6	Systematic Principle	Adopting a multi-level hierarchical structure, the indicators are clearly layered, mutually independent, and comprehensively coordinated, forming a complete evaluation system.

2.2.2. Indicator Screening and Hierarchical Structure Development

This study integrates literature review, industry standards, and an improved TF-IDF method for extracting user demands. After extensive discussions among multiple experts in human factors engineering and advanced vehicle R&D, indicators with low relevance, poor distinguishability, or non-quantifiability were eliminated, ultimately establishing a three-tier hierarchical evaluation system comprising the objective layer, criterion layer, and indicator layer. The objective layer represents the overall premium experience level of passenger vehicles. The criterion layer includes five core dimensions—sensory quality, dynamic ride experience, intelligent interaction, scenario adaptability, and emotional value—forming a composite evaluation structure that combines universality with differentiation.

2.3. Theoretical Foundation of the Mathematical Model

2.3.1. Improving the TF-IDF Topic Keyword Extraction Model

TF-IDF stands for Term Frequency-Inverse Document Frequency, a classic algorithm in text mining and keyword weighting. In the paper, it is used to quantify the importance of high-end user experience requirements and to screen core evaluation indicators. TF refers to the frequency of a target keyword appearing within an individual user text sample, representing the intensity with which this requirement is mentioned in a single user feedback. IDF, or Inverse Document Frequency, measures how common a keyword is across the entire corpus of samples, helping filter out generic, non-differentiating terms and retain key, distinctive user needs[2-3].

This paper employs an improved TF-IDF text mining model to extract key demand terms from in-depth interviews with high-end users and open-ended experience feedback. The model overcomes the limitations of traditional frequency-based approaches, which rely solely on word occurrence rates, by innovatively introducing a weighting coefficient for degree adverbs. This assigns differentiated score levels to modifier words, thereby precisely quantifying users' attention intensity and perceived importance toward various experience factors. By combining the keyword weight rankings generated by this model with expert group discussions, low-frequency or weakly relevant demands can be effectively filtered out, while highly sensitive indicators are preserved. This provides objective, quantitative data support for constructing the indicator layer of the evaluation system, ensuring that the final selected indicators closely align with the genuine perceptions and preferences[4] of high-end users. The mathematical expressions for TF, IDF, and degree adverb weights are presented in formulas (1), (2), and (3), respectively.

$$TF_i = \frac{N_i}{1+N_i} \tag{1}$$

Formula (1) analysis: Formula (1) analysis: TF_i represents the improved term frequency of the i -th keyword; N_i denotes the number of occurrences of the keyword in user feedback texts. A nonlinear function is used to constrain the upper limit of term frequency, preventing frequency bias caused by individual language habits.

$$IDF_i = \log(\frac{N}{N_i} + \lambda) \tag{2}$$

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Formula (2) analysis: IDF_i denotes the inverse document frequency, where N is the total number of sample texts, N_i is the number of texts containing the i -th keyword, and λ is the empirical correction coefficient. This coefficient is introduced to prevent division-by-zero errors during computation.

$$w_i = \frac{\lambda \cdot TF_i \cdot IDF_i}{\sqrt{\sum_{i=1}^{m} (\lambda \cdot TF_i \cdot IDF)^2}} \tag{3}$$

Formula (3) analysis: w_i represents the comprehensive weight of keywords, and λ is the coefficient of degree adverbs, through which precise weights for each experience requirement can be obtained via normalization.

2.3.2. Fuzzy Comprehensive Evaluation Model

Fuzzy comprehensive evaluation theory offers significant advantages in addressing complex assessment problems involving both fuzziness and uncertainty, particularly suitable for subjective and ill-defined evaluation objects such as high-end user experiences. This paper introduces fuzzy mathematical methods into the quantitative study of premium passenger vehicle experiences. Addressing the practical challenges of users' subjective descriptions—such as semantic ambiguity and varying degrees of intensity—across dimensions like sensory quality, driving dynamics, and interactive feedback, we construct a structured fuzzy evaluation matrix. This transforms collected qualitative data into membership functions, which are then combined with indicator weights determined through the Analytic Hierarchy Process (AHP) via fuzzy synthetic operations. As a result[5-6], originally intangible subjective perceptions are mapped into comparable, rankable numerical scores. This process not only enables a scientific transformation from qualitative descriptions to quantitative ratings but also establishes experience grade intervals based on composite scores, allowing different vehicle models to be clearly categorized within a unified evaluation framework. Compared to simple weighted scoring methods, fuzzy comprehensive evaluation better preserves the inherent uncertainty in user assessments, avoiding information loss and arbitrary truncation, thereby enhancing the reliability of evaluation outcomes. It provides a robust data foundation[7] for subsequent vehicle experience benchmarking and prioritization of iterative improvements.

This paper employs fuzzy comprehensive evaluation to convert multi-level indicator scores into overall experience ratings, thereby quantifying the level of experience. The core mathematical formula of fuzzy comprehensive evaluation is shown in Equation (4).

$$S = W \cdot R \cdot V^T \tag{4}$$

Formula (4) analysis: S represents the comprehensive score for high-end experience, W is the indicator weight vector, R is the fuzzy evaluation matrix, B is the comprehensive evaluation membership vector, and V is the rating level vector.

3. Experimental Design

3.1. Overall Experimental Design

To address the inherent limitations of traditional research methods in high-end automotive scenarios—such as strong subjectivity, disconnection from real-world contexts, and insufficient sample representativeness—this study adopts an approach characterized by "full coverage of market segments, real-vehicle testing, in-depth user engagement, and synchronized multi-source data collection". Focusing on five categories of premium vehicles—sedans, SUVs, MPVs, off-road vehicles, and sports cars—the research selects Chengdu and Shenzhen, two core consumer cities known for their vibrant consumption activity and distinct regional characteristics, as key survey locations. Through on-road testing under realistic driving

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conditions and typical travel tasks, the study systematically captures multimodal data including users' operational behaviors, physiological responses, and subjective evaluations. The entire methodology aims to capture valid data under authentic driving conditions while accounting for experiential differences across regions and usage scenarios, thereby providing a solid and reliable foundation of primary empirical evidence for subsequent evaluation model development.

3.2. Standardized Experimental Environment Setup

Five dedicated testing scenarios were established based on the core usage contexts of premium models across five sub-markets, as shown in Table (2) below.

Table 2: Establishing Five Types of Dedicated Experimental Scenarios

Serial Number	Model	Driving scenarios
1	Luxury sedan	Urban business commuting and high-end hospitality settings
2	Premium SUV	Urban premium travel and suburban family outings
3	Premium MPV	Business hospitality and high-end group travel scenarios
4	High-end off-road vehicle	Urban commuting and extreme off-road outdoor scenarios
5	High-end sports car	Urban short-distance cruise and track handling experience scenarios

4. Analysis of Differentiated Experiences Across Dimensions

4.1. Emotional Value Experience Dimension

High-end models across different market segments show significant divergence in emotional experience. Sedans and sports cars stand out particularly in identity recognition, brand prestige, and emotional resonance in driving, thanks to their strong social symbolism and high level of driver engagement, generating the strongest emotional responses from users. In contrast, MPVs and SUVs, positioned more toward practical use cases such as spacious cargo capacity and multi-passenger travel, focus user experiences primarily on functional suitability and ride comfort, leaving limited room for emotional value creation and resulting in a relatively rational overall perception. Off-road vehicles, meanwhile, deliver intense feelings of conquest and control in extreme terrain scenarios, achieving notable peaks in emotional experience; however, their emotional impact is weaker in urban commuting and everyday usage environments, making it difficult to maintain consistent emotional engagement. Overall, emotional value development remains uneven across categories—sedans and sports cars dominate in emotional appeal, while MPVs, SUVs, and off-road vehicles still have substantial room for improvement in shaping emotional connections under normal usage conditions.

4.2. Dynamic Driving Experience Dimension

High-end sports cars and off-road vehicles lead in dynamic driving performance evaluations, scoring highly in areas such as instant throttle response, steering precision, body control, and adaptability to complex road conditions—characteristics that align closely with their sporty or extreme off-road-oriented product identities. Premium sedans follow a different technical path, emphasizing refined suspension tuning and smooth ride quality to deliver a sense of riding comfort, effectively meeting the demands of both urban business travel and long-distance journeys. In contrast, MPVs reveal clear shortcomings in dynamic performance, including insufficient smoothness during acceleration and vague and imprecise steering feedback, making it difficult to meet high-end users' consistent expectations for driving quality. This

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weakness has become a major barrier to improving overall MPV driving experience and should be prioritized as a key technical focus in future model updates and development.

4.3. Sensory and Textural Experience Dimension

In terms of sensory and tactile quality, premium sedans and MPVs clearly outperform other vehicle types, excelling particularly in interior material feel, assembly precision, cabin noise insulation, and ambient atmosphere creation—features that closely align with users' demanding expectations for ride comfort in business settings. In contrast, off-road vehicles and sports cars lag behind in this dimension, primarily due to insufficient noise reduction, lower refinement in interior details, and subpar static ride comfort. Their design focuses more on mechanical performance and operational adaptability, resulting in a diminished perception of luxury during everyday use. SUVs demonstrate relatively balanced performance across all metrics, without significant weaknesses or standout strengths, offering a neutral overall sensory experience that effectively meets the quality demands of diverse family travel scenarios.

4.4. Smart Interaction Experience Dimension

The overall smart interaction experience scores for traditional ultra-luxury vehicles across the five major segments remain relatively low, with common issues including delayed system updates, complex interaction logic, limited scenario adaptability, and insufficient personalization. Among these, high-end sedans and SUVs offer relatively better smart experiences, while sports cars, off-road vehicles, and MPVs exhibit significant shortcomings. Traditional ultra-luxury models tend to emphasize hardware craftsmanship at the expense of intelligent features, creating a clear disconnect from today's premium users' demands for intelligent, scenario-based interactions.

4.5. Scene Adaptation Experience Dimension

Different market segments exhibit the most distinct adaptation characteristics: MPVs are best suited for business reception scenarios, offering clear advantages in privacy protection, multi-passenger accommodation, and ceremony creation; SUVs stand out with strong adaptability across multiple family-oriented scenarios; sedans focus narrowly on urban business settings, resulting in relatively limited scenario compatibility; off-road vehicles are only suitable for extreme terrain conditions, lacking practicality for everyday city driving; sports cars have the narrowest application range, ideal solely for short-distance performance experiences, with poor daily usability and scenario versatility.

5. Research Findings, Limitations, and Future Perspectives

5.1. Main Research Findings

This paper constructs and validates a high-end experience evaluation system by leveraging five premium niche markets, through human factors experiments, user research, and mathematical modeling. The key conclusions are as follows:

(1)Premium experience is a synergistic system encompassing sensory quality, dynamic driving, intelligent interaction, scenario adaptation, and emotional value, with refined perception and scenario-specific experiences at its core—differing fundamentally from the hardware-centric approach of conventional family vehicles.

(2) Experience weight varies significantly across sub-segments: sedans emphasize business ceremony and quiet comfort; MPVs focus on private reception scenarios; SUVs highlight all-around space immersion; off-road vehicles prioritize stability in extreme conditions; sports cars stress dynamic handling and emotional value. Evaluation should differentiate by segment characteristics to avoid homogenized standards.

(3) Traditional ultra-luxury vehicles have shortcomings in intelligence, personalization, and fine-tuning, and the competitive advantage has shifted toward scenario-based experiences and enhanced smart features.

(4) Human factors-based empirical research and modeling can effectively transform subjective user needs into technical development specifications, connecting the entire chain from user experience to product iteration, thereby providing a scientific foundation for forward-looking development of premium vehicles.

5.2. Research Gaps and Future Perspectives

Although this study has conducted a systematic investigation, it still has the following limitations: the sample primarily comes from top-tier cities in China, excluding user needs from second- and third-tier cities as well as overseas markets; experimental scenarios are concentrated on typical road conditions and seasons, without covering extreme climates; and the evaluation system is based solely on new vehicle conditions, lacking data on material degradation and experience changes over long-term use.

Future development can be advanced in three aspects: first, expanding the sample coverage to include vehicles and users from diverse regions, climates, and usage cycles, thereby enhancing the system's universality; second, conducting 1-3 year long-term tracking experiments to monitor experience degradation patterns and identify durability-related R&D indicators; third, integrating AI and big data technologies to build a dynamic, iterative evaluation system that enables real-time collection of user experience data, automatic updating of metrics, and intelligent optimization of R&D strategies. This will drive high-end experience evaluation toward standardization, intelligence, and normalization, providing continuous support for premium breakthroughs by domestic brands and the refinement of industry standards.

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