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RESEARCH ARTICLE

Research on Market Competitiveness Assessment Methods of Smart Home Enterprises Under the Perspective of Long-Term User Experience

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ABSTRACT Since the 20th century, there has been a wave of digitalization in homes and businesses worldwide, and smart homes have gradually become a high-profile business sector. However, behind fierce competition in the digital home market, the importance of user experience for companies to enhance their competitiveness as a business model for providing services to home users is often overlooked. Combining the industry's basic theories and our own empirical research, this study expands the assessment perspective and assessment methods on the basis of the industry's existing assessment methods and constructs a comprehensive assessment system that is both innovative and practical - the Smart Home Product Competitiveness Index (PCI). The index constructs a three-in-one smart home product competitiveness index assessment system for brand power, product power, and marketing power from the perspective of long-term user experience. Twelve representative enterprises were selected from the five categories of camps, covering three demand levels, six typical scenarios, and 17 mainstream products. This study shows that Internet enterprises are characterized as all-round. Traditional home appliance manufacturers, Internet enterprises, and communication carriers must strengthen the construction of product power. The competitiveness assessment method for digital home enterprises from the perspective of long-term user experience proposed in this study is effective and can provide a reference for subsequent related studies.

INDEX TERMS Smart home, user experience, long-term perspective, analytic hierarchy process, fuzzy comprehensive evaluation.

I. INTRODUCTION

With the rapid development of 5G, 6G, IoT, and AI technologies, the digital home sector is experiencing unprecedented technological change [1], [2], [3]. These technologies bring greater connectivity, intelligence, and automation to the digital home, thereby significantly improving the convenience and comfort of home life. Digital technologies are bringing about huge changes and opportunities for the digital home [4], [5], [6], [7], [8], [9], which will become a smarter, more connected, and automated living space as these technologies are further developed and applied.

Since the 20th century, homes and businesses in China and around the world have rapidly turned into digital solutions. In this wave of digitization, smart homes have become an area of great interest. Among other things, digital home companies create a more convenient, efficient, and comfortable home life experience for users by providing solutions such as smart homes, smart devices, and Internet services. However, behind the fierce competition in the digital home market, the importance of user experience as a business model for providing services to home users is often overlooked. From the user experience perspective, we must recognize the importance of measuring the development of the digital home business and its significant impact on users and the market. User experience is not just about how good a product or service is; it is about the feelings and satisfaction gained through the

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user's interaction with the digital home company, and during the use of products and services. From the perspective of achieving excellent user experience, we explore how to help smart home companies establish a positive corporate brand image, enhance user usage stickiness, increase product sales, and ultimately improve the overall competitiveness of the market. In recent years, scholars at home and abroad have conducted multifaceted studies on the influencing factors of smart home companies' competitiveness from multiple research perspectives and methods.

From a user experience perspective, Alam et al. suggested that one of the main goals of smart home research is to ease daily life by improving user comfort through human activity recognition, event automation, and remote home management [10]. Meanwhile, Marikina et al. focused on the long-cycle user perspective of the smart home business, and while analyzing the psychological and technological factors of smart home technology adoption, exploring the changes in perceptions of the technology pre- and post-adoption will help to understand the cognitive process of technology adoption, and examining and understanding the behavioral changes will help to facilitate the implementation of the technology in the mass market [11]. In addition, several studies have focused on the impact of perceived user value on the competitiveness of smart-home companies. For example, Tang et al. study aimed to reveal the impact of smart home platform elements on consumer value perception, which consumers perceive as a connection between the modularity of smart home products and consumers. In addition, consumers who perceive the value of platform services can indirectly perceive the value of smart home products through modularity and inter-consumer connectivity [12].

Service quality is an important factor in assessing the competitiveness of smart home companies. For example, Gu et al. empirically analyzed sample data from respondents with a smart home use experience and demonstrated that the service quality and perceived usefulness of smart home services positively affect user satisfaction, which in turn contributes to the formation of user habits. Users' desire to consistently use smart home services is influenced by perceived usefulness, satisfaction, and habituation, with habituation being a key factor influencing their willingness [13]. Liu et al. This study explored the factors influencing Chinese users' perceived trust in voice-enabled smart home systems, and developed a model that included six variables: system quality, familiarity, subjective norms, technological optimism, perceived enjoyment, and perceived trust. The results showed that system quality was a significant influencing factor affecting all other variables, and perceived enjoyment was the most directly affected variable, influenced by system quality, subjective norms, and technological optimism [14].

In addition, there have been a number of studies that have looked at smart home technologies, and the implications for the competitiveness of smart home companies. Sovacool et al. suggest that the widespread diffusion of smart home technologies relies on a complex confluence of factors, and that it is likely to continue to occur in isolation, rather than across multiple bundled systems. Future research should focus on the experiences of actual adopters and expand the notion of control [15]. Kim et al. suggested two areas of focus for research in developing competitive smart home products: intelligence for personalized user experience and intelligence for extended collaboration, attributes that can contribute to achieving competitive smart homes [16]. Chong et al. suggested that enhancing consumer acceptance of the positive dimensions of technology would help users achieve self-actualization and self-management. However, technologies that make domestic life and physical homes more reliable, less prone to risk, and more secure while further eroding social relationships and trust [17].

Despite the fact that there have been many studies on the factors influencing the competitiveness of smart home companies, there are still some limitations. First, although scholars have mentioned the impact on user attitudes before and after the adoption of smart home technologies, few studies have assessed smart home companies' market competitiveness from a long-term user experience perspective. Second, current research on the assessment of smart home companies' market competitiveness has focused on factors such as service quality, product positioning, and user experience; however, research has focused on the factors influencing users' desire to continue using smart home services. In addition, although some studies have focused on the impact of user feedback on the competitiveness of smart home companies, most have concentrated on aspects such as system quality and user-perceived enjoyment and have lacked in-depth and systematic exploration of other important influencing factors [18].

From a long-term user research perspective, Karapanos and Hassenzahl et al. conducted an evaluative study of user experience based on the time dimension [19]. A few years later, they conducted an experimental study based on the influencing factors of the long-term user experience of smartphones [20], which extended the research dimension of user experience to the long-term stage and concluded that the influencing factors of user experience would change with the passage of time. Li and Wu conducted a study on the overall user experience design based on the time dimension, which studied the interrelationships and influences of the four dimensions [21]. Han et al. studied the stage influence elements of user experience of intelligent connected products from the time dimension, analyzed the experience and interaction mode of existing intelligent connected products based on the user experience theory and interaction design method, combined with relevant quantitative research, and constructed a cyclical experience element model of intelligent connected products based on the cyclical characteristics of the time dimension [22].

Based on the above research limitations and innovations, this thesis considers factors such as service quality, user experience, and users' willingness to continue using technology from a long-term user experience perspective to assess the

market competitiveness of smart home companies. Delving into the feedback from actual users of smart home technologies will provide smart home companies with substantial suggestions on how to improve their market competitiveness. The study utilizes the Analytic Hierarchy Process (AHP), a comprehensive and systematic analysis method [23] that is widely employed in model development, risk assessment, and countermeasure recommendation [24], [25], [26]. In this study, AHP is integrated with user research perspectives to establish a more specific evaluation index system. Literature research, in-depth interviews, and network research were combined to construct the system, along with two rounds of the Delphi method and AHP integration. The aim is to provide precise reference indices for enhancing the competitiveness of smart home enterprises. An experimental assessment was conducted to gauge the practical application of the model in industry. To account for cultural and national contexts, 12 representative smart home-like enterprises in China were selected as subjects for comparative analysis, affirming the model's feasibility. Through experimentation, the model was standardized, leading to the establishment of a complete evaluation system.

The subsequent sections of this paper are structured as follows: Section II outlines the main methodology and detailed steps implemented in this study, and Section III elucidates the approach for determining the assessment subject, assessment category, and assessment index. Section IV assesses enterprise competitiveness by analyzing the performance of each index using the evaluation model, thereby constructing a standardized design for the evaluation process. Finally, Section V provides a comprehensive conclusion.

II. METHODOLOGY

This study adopts a combination of qualitative and quantitative methods, using the literature research method, network research method, and real user survey method to obtain the evaluation index system, and then uses the Delphi method [27] to screen the index system, using the method of collecting and integrating expert opinions, and through the expert's knowledge and experience to carry out the index screening, to improve the accuracy and comprehensiveness of the screening results [27], [28], [29]. After determining the indicator system, AHP hierarchical analysis was used to determine the weights. Finally, the questionnaire data obtained in the model application experiments were tested for differences to validate the model further, and the experimental process was constructed as a standardized evaluation process. The overall research process used in this study is illustrated in Figure 1.

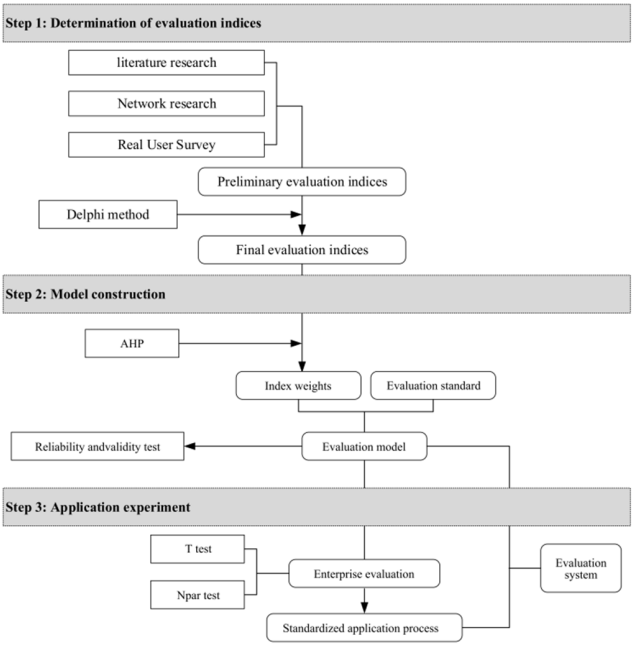

FIGURE 1. Overall research process.

A. INTERVIEWS AND INTERNET RESEARCH

Prior to conducting user research, it is necessary to first undertake the design of a user research questionnaire. Regarding the sampling design process, the database for the construction of this indicator originates from the smart home user experience assessment questionnaire survey, and we designed a scientific and rigorous survey program to ensure the accuracy of data collection. The survey objects were real users of smart home products. A real user is defined as one who has used at least three of the 17 smart home products and has been using them for not less than three months. The prerequisite for using smart home products is that broadband networks have been installed at home, which creates the conditions for adopting the online survey. The online survey not only improves the efficiency of survey implementation but also facilitates real-time monitoring and control of the quality of implementation in order to make timely responses and adjustments.

The online survey was conducted nationwide, with sample quotas based on the division of the country's geographic area (Northeast, North China, East China, Central China, South China, and West China), and, at the same time, sample micro-adjustments were made by using a number of variables representing demographic characteristics, such as gender, age, and family structure, to try to ensure that the sample distribution was in line with the overall distribution pattern. In addition, considering that each category of smart home product needs to be analyzed separately, a minimum sample size of 30 needs to be ensured.

In terms of the correspondence between the questionnaire board and the indicator system, the main framework of the questionnaire is designed with the user experience of the 17 smart home products as the main line, and the questions contained in each product constitute an independent board, and in order to facilitate the comparison between smart home products of different categories, the structure of each independent board and the questions contained in each board are the same, including three sub-modules, namely, branding power, product power and marketing power, and

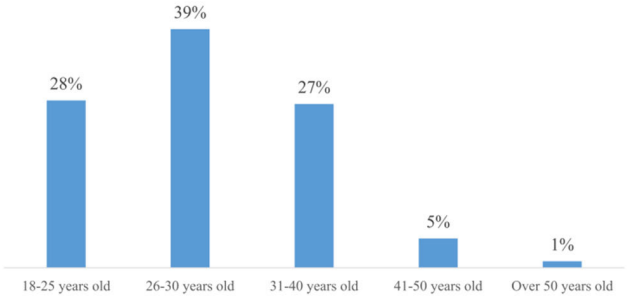

FIGURE 2. Age distribution of the sample.

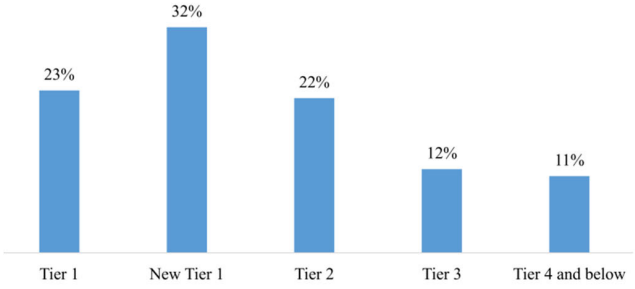

FIGURE 3. Distribution of the sample by city level.

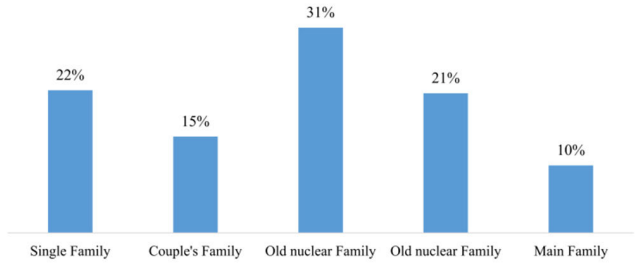

FIGURE 4. Household structure distribution of the sample.

each sub-module contains questions corresponding to the three-level indicators. Each sub-module contains questions corresponding to the three-level indicators, and each question is evaluated using a 5-point scale, which not only facilitates the respondents to follow a uniform measurement scale but also facilitates the standardized processing and analysis of the data afterwards.

This study relied on the index system to construct the research questionnaire, with 1,518 valid samples recovered, and the data time was March 2023. To present a clear picture of competition in the smart home market, this study is divided on the premise of ensuring the effective coverage of five types of mainstream industry camps, 12 representative companies, and 17 key categories, combined with factors such as gender, age, living area, and family structure, to guarantee the validity and scientificity of the research results. The specific sample information is as follows:

- **Gender:**68.3 per cent of respondents were male and 31.7 per cent were female.
- **Age:** Respondents were predominantly young and middle-aged users aged 18-40, accounting for 94 per cent of the overall share, as shown in figure 2.
- **Cities:**67 per cent of respondents live in cities of tier 2 or higher, with up to 32 per living in the new tier 1, as shown in figure 3.
- **Family structure:** The two-generation family structure of husbands, wives, and children is predominant, with 52 per cent of new and old nuclear family users, as shown in figure 4.
- **Geography:** The distribution of respondents and enterprises is consistent with the fact that leading enterprises are mainly concentrated in the eastern provinces and cities, among which Guangdong Province,with more than 150,000 related enterprises, is known as the cradle of China's smart home industry development.

B. A CYCLICAL MODEL OF USER EXPERIENCE FROM A LONG-TERM EXPERIENCE PERSPECTIVE

Short-term user experience and long-term user experience are two relative user experience categories divided from the perspective of time duration, in which short-term user experience focuses on a single behavioral event, such as the instantaneous web page loading experience, the experience of using the product within a few hours, and the usefulness of the product is a key feature that affects user experience. Long-term user experience focuses on multiple, long-term interactions between users and the product, from the user's understanding of the product information, initial use, and product maintenance until the complete abandonment of the use of the product. Different contact phases will have a different impact on the overall user experience. Long-term experience not only focuses on the functional experience but also cultivates an emotional connection between the user and the product and the brand behind the product.

From the perspective of long-term user experience, this study establishes a three-in-one comprehensive competitiveness assessment system, focusing on the three phases of user experience: experience-interaction-promotion [30], and constructs a three-in-one smart home index assessment system for brand power, product power, and marketing power, as shown in figure 5. It builds a comprehensive competitiveness index evaluation system for brand, product, and marketing power, which can evaluate the competitiveness of market participants in a more scientific, comprehensive, and effective way.

We should treat the user's long-term user experience of using a product. The user's previous experience affects his/her interaction process with the product, the experience of the interaction process is good or bad to determine the user's purchasing decision of the product, and when experiencing a new product, the previous interactions and expectations are also transformed into his experience [31]. The experience brought about by each product the user meets is a cyclic cycle, and these relatively independent user experience cycles are linked together in the time dimension to form the user's long-term user experience. Therefore, we should not only focus on the interaction phase of the short-term experience process

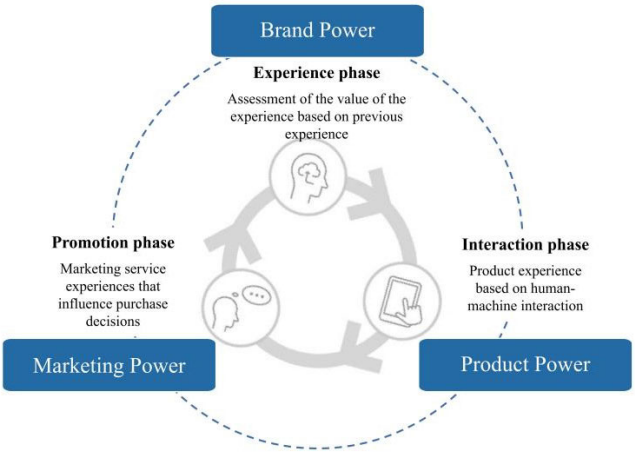

FIGURE 5. Trinity assessment system for brand, product and marketing power.

but also on the influencing relationship between experience, interaction, and facilitation.

The three stages of experience, interaction, and promotion are relatively independent, but closely linked. First, at the initial stage, when users start to contact the product, they tend to interact with the product by relying on their own experience, which in turn largely determines the good or bad experience, that is, brand power plays a key role in this stage. Second, when users gradually familiarize themselves with the product, the interaction between users and the product is the main source of long-term user experience, that is, product power is crucial at this stage. Finally, when users understand the attributes and performance of a product, the subsequent soft services and marketing experience become crucial; that is, marketing power becomes a key factor affecting the user's purchase decision. These three stages can be distinguished as the experience, interaction, and promotion stages, corresponding to the three core elements of brand, product, and marketing power.

C. AHP HIERARCHICAL ANALYSIS

AHP hierarchical analysis was proposed by the American operations researcher Satie, whose principle is to treat the complex problem as a system, decompose the elements related to decision-making into objectives, criteria, program layers, etc., and finally obtain the optimal program by solving the weights of the indicators of the lower layers to the upper layers [32]. The weight determination process quantifies the subjective evaluation of the experts and can test the consistency of the decision-makers' evaluations. The AHP hierarchical analysis method consists of three steps.

Step 1: Scale determination and construction of the judgement matrix. Constructing a pairwise judgement matrix by comparing the importance of each element of a particular layer with the element of the previous layer, this study uses a 1-5 scale (minimum of 1 and maximum of 5) as a criterion for pairwise comparisons, and pairwise comparisons were made using consistent matrix rows to obtain the relative proportions.

Step 2: Eigenvector value calculation and consistency test analysis. The CR is used as the test standard for the consistency of the judgement matrix, where CR = CI/RI, and the value of CR is less than 0.1, indicating that it passes the consistency test, and vice versa indicates that it does not pass the consistency test.

Step 3: The weights of the elements in each layer are calculated. If the judgement matrix passes the consistency test, the weights can be calculated, and then the final score of the target can be calculated based on the average value of the scores of the indicators at the program level.

III. CONSTRUCTING A USER EXPERIENCE ASSESSMENT MODEL FOR SMART HOME COMPETITIVENESS

A. DETERMINATION OF THE SUBJECT OF THE ASSESSMENT

From the supply perspective, the market has become increasingly complex with multiple competition patterns [33]. In the face of the vast market space of the smart home industry, all types of enterprises are actively involved, relying on their own resource endowments and core competencies to enter and layout the market. Currently, it is mainly divided into five types of camps: hardware enterprises, Internet enterprises, and traditional home appliance enterprises. This study selected 12 representative enterprises in five types of camps, including Xiaomi, Huawei, Baidu, Alibaba, Midea, Haier, Gree, China Telecom, China Mobile, China Unicom, EZVIZ, and Imou, as shown in Table 1.

B. DETERMINATION OF ASSESSMENT CATEGORIESD

This study is based on the evolution of Maslow's hierarchy of needs theory [34], which classifies smart home application scenarios into three major levels of demand based on the user's degree of intelligent demand: basic demand, improvement demand, and advanced demand, as shown in figure 6.

Maslow's Hierarchy of Needs Theory is a taxonomic model of human needs that proposes five levels of need, which gradually escalate in a certain order: when one level of need is satisfied, a higher level of need is pursued. We made a one-to-one correspondence with the three stages of user needs [35].

First, the physiological and safety needs of people to maintain their own survival and safeguard life safety are among the most basic human needs, such as intelligent home appliances to meet the basic survival needs of human beings for drinking water and eating, and security monitoring to meet the safety and protection needs of human beings, which mainly provides users with a home life that meets the basic configurations; therefore, this stage is defined as the basic needs stage.

Second, social demand is the desire to establish emotional ties after the basic needs are satisfied, as intelligent light sensing and audio-visual entertainment products are mainly used to meet people's spiritual life and home social needs,

TABLE 1. Smart home industry market by type of player.

Type	Represented companies	Full business launch time	Monthly active user size (February 2023, million)	Strengths & Core Competencies
Hardware companies	Xiaomi	2017	6686	A strong competitor in the market with full category coverage, internet ecosystem as a key barrier and obvious technological advantages
	Huawei	2015	2889	
Internet companies	Baidu	2018	1159	Use Smart speaker to cut in and master the interactive portals and make them blockbusting, and take advantage of content operation and Internet technology
	Alibaba	2020	757	
Traditional home appliance companies	Midea	2014	998	Traditional home appliance manufacturers transforming to shape complete home scenarios with natural brand barriers and channel advantages
	Haier	2013	483	
Communication operators	China Telecom	2017	2491	Has a huge user base, controls the core gateway products, and introduces third-party hardware and services through its platform. Sales are mainly in the form of bundles with broadband.
	China Mobile	2017	2341	
Vertical companies	EZVIZ	2015	3692	Breakthrough in the vertical market where its strengths are highlighted, focusing on building the value and reputation of vertical products and deepening the home security hardware
	Imou	2015	2000	

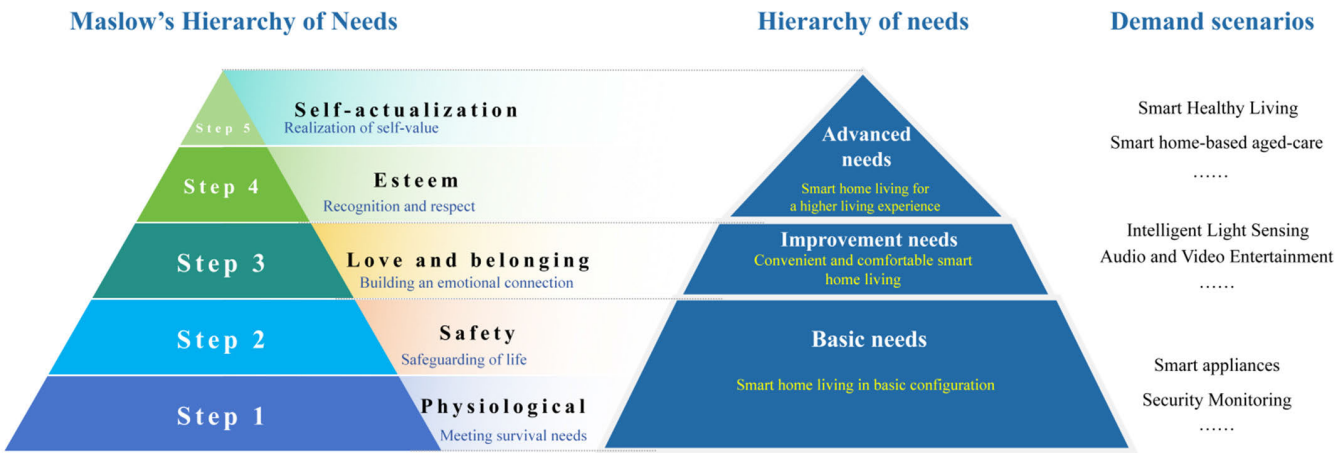

FIGURE 6. Hierarchy of requirements for digital home application.

and further provide a convenient and comfortable home life on the basic needs, so this stage is defined as the stage of improving demand.

Third, dignity demand belongs to the pursuit of individuals at a higher level, such as home care and healthy living category of non-demanding products, which can help users with more dignity and shape a more healthy external image; currently, there are no products in the field of smart homes that can satisfy the demand for self-fulfillment. Such products provide consumers with a higher-order intelligent living life; thus, this stage is defined as the advanced demand stage.

This study covered three types of demand levels: six typical scenarios and 17 mainstream products, including smart door locks, smart cameras, visual doorbells, smart TVs, smart air conditioners, smart lamps and lanterns, smart curtains, smart switches, and smart speakers, as shown in table 2.

C. DETERMINATION OF ASSESSMENT INDICES

1) INITIAL DETERMINATION OF ASSESSMENT INDICES

Combined with previous literature research and user interviews, the preliminary index system is obtained by extracting the content keywords based on semantic analysis, and the indexes at all levels are established using the top-down thinking method,as shown in figure 7. This study carried out a more comprehensive dismantling and combing of the overall competitiveness and complete coverage of the diagnosis of brand power, product power, and marketing power to enhance the system's interpretation of overall competitiveness. The brand power of X1, product power of X2, and marketing power of X3 are used as the first-level indicators. Under this framework, 9 secondary indicators and 23 tertiary indicators were proposed, and each tertiary indicator proposed a corresponding description to clarify its connotation. After two

TABLE 2. Digital home application scenarios and specific categories covered in the study.

Hierarchy of needs	Demand scenarios	Specific categories	Sample size
Basic needs	Security Monitoring	Smart lock	244
		Smart Camera	351
		Visual doorbell	145
	Smart appliances	Intelligent TVs	385
		Intelligent air conditioning	311
Improvement needs	Intelligent Light Sensing	Intelligent luminaires	204
		Intelligent curtains	168
		Intelligent switche	274
	Audio and Video Entertainment	Smart speaker	411
		Voice remote control	210
		Early Learning Robot	121
		VR headsets	127
Advanced needs	Smart Healthy Living	Smart Sensors(smoke, flood, gas)	139
		Smart Fitness Mirror	53
		Intelligent Environmental Monitor	79
	Smart home-based aged-care	Intelligent health monitoring device	246
		Smart Call Alarm	31

rounds of the Delphi method, the experts' opinions converged and the final evaluation indicators were determined.

2) BRAND POWER INDEX

Brand power, as a core element in measuring the market competitiveness of enterprises, directly affects consumers' purchasing decisions [36]. To assess brand power more accurately, this study refers to the brand triangle diagnostic model [37] to determine the specific measurement of brand power.

The brand triangle diagnostic model provides a comprehensive framework for assessing brand power, and this study evaluates brand power in terms of brand awareness, brand loyalty, and brand reputation. Brand awareness focuses on the degree of recognition and spread of the brand in the target market; brand loyalty measures consumers' trust and long-term support for the brand; and brand reputation focuses on the positive image and values of the brand in the minds of consumers. By systematically analyzing brand awareness, brand loyalty, and brand reputation, we can gain an in-depth understanding of the brand's performance in the marketplace and develop a more effective brand strategy.

3) PRODUCTIVITY INDEX

Product power is an important indicator for measuring the strengths and weaknesses of smart home products, in order to more accurately assess the comprehensive performance of the product, this paper will refer to the industry group standard Smart Home Evaluation Indicator System (T/CESA 1138-2021) as well as the three-level model of user experience in the academic world [38], to make specific measurements for product power.

At the secondary indicator level, this study evaluates product power from three aspects: aesthetic emotion, technical function, and utility value [39]. Aesthetic emotion focuses on the aesthetic experience of a product in multiple dimensions, such as visual, auditory, and tactile; technical function emphasizes the functionality, operability, and other technical characteristics of the product; and utility value focuses on the practicality and cost-effectiveness of the product in practical application scenarios.

Further refined to three-level indicators, we evaluate the product from multiple perspectives, such as good looking, good sounding, usability, usefulness, timesaving, and effort saving [40]. Among them, good looking and good sounding evaluate the aesthetic performance of the product from the visual and auditory perspectives, respectively; usability focuses on the ease of operation and the reasonableness of the user interface design, which is used to measure whether the functions provided by the product satisfy the user's needs; and time-saving and effort-saving focus on whether the product can save time and reduce the user's burden in the process of using the product.

4) MARKETING POWER INDEX

Marketing power is one of the key factors to measure the performance of the product in the market competition, in order to assess the competitiveness of the marketing field in a more systematic way, this paper takes the classic 4P marketing theory in the field of marketing (product, price, channel location, promotion and extension) as the theoretical basis [41], and realizes the collection and organization of the user evaluation elements [42] through the user interviews and the card sorting method (the product elements have already been studied in depth in the part of the product power index, the This part will not be involved again), and finally determine the specific measurement content of marketing power. First, 30 representative users who could clearly express their own opinions were selected for in-depth interviews to collect the elements that affect the marketing experience that the users are concerned about. Second, the card classification method

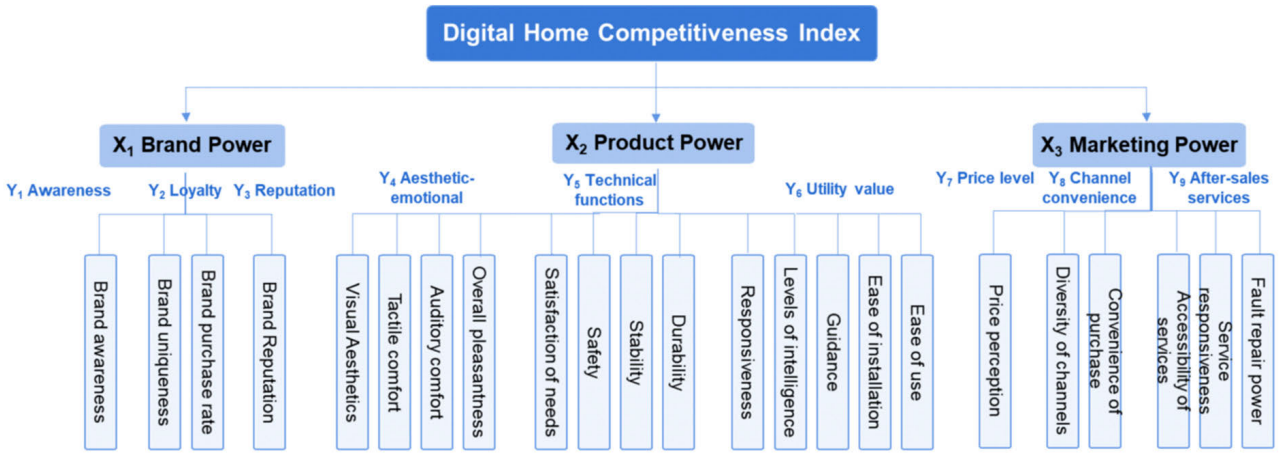

FIGURE 7. Indicators at each level of the assessment system.

is used to organize the evaluation elements, relying on the 4P marketing theory model to classify the influencing elements of user feedback, and then adding or merging certain elements on this basis to finally obtain the specific measurement content of the marketing power dimension.

At the level of secondary indicators, this study evaluates marketing power in terms of price level, channel convenience, and after-sales services [43]. The price level indicator focuses on whether the pricing of the product is reasonable and whether it can attract target users; channel convenience focuses on the convenience of the product in sales and distribution, whether the coverage is extensive; and after-sales service focuses on the support of the product in terms of maintenance, return, and exchange of goods after the purchase, as well as customer satisfaction.

5) DETERMINATION OF WEIGHTS AND MEASUREMENTS

A hierarchical AHP analysis was used to determine the weights of the indicators. A total of 1,518 users were invited to judge and rate the relative importance of the nine secondary indicators, and a judgement matrix was constructed as shown in table 3.

For the nine secondary indicators to construct a judgement matrix and carry out AHP hierarchical method research (calculation method: sum and product method), the analysis obtained the eigenvectors are (1.010, 0.588, 0.643, 0.988, 1.251, 1.251, 1.178, 0.971, 1.122), The nine corresponding weights are X as follows X1 = 11.222%, X2 = 6.528%, X3 = 7.150%, X4 = 10.973%, X5 = 13.895%, X6 = 13.895%, X7 = 13.087%, X8 = 10.786%, X9 = 12.465%. In addition, the maximum eigenroot (9.000) can be calculated by combining the eigenvectors, and then using the maximum eigenvalue to calculate the CI value (0.000) [CI = (maximum eigenroot - n)/(n-1)], which is used for the consistency test, as shown in table 4.

In this study, a 9th order judgement matrix was constructed, corresponding to the above table, which can be queried to obtain the random consistency RI value of 1.360, and the RI value is used for the following consistency test calculation use, as shown in table 5.

TABLE 3. A 9th-order judgement matrix.

	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9
Y_1	1	1.719	1.570	1.023	0.808	0.808	0.857	1.040	0.900
Y_2	0.582	1	0.913	0.595	0.470	0.470	0.499	0.605	0.524
Y_3	0.637	1.095	1	0.652	0.515	0.515	0.546	0.663	0.574
Y_4	0.978	1.681	1.535	1	0.790	0.790	0.838	1.017	0.880
Y_5	1.238	2.129	1.943	1.266	1	1	1.062	1.288	1.115
Y_6	1.238	2.129	1.943	1.266	1	1	1.062	1.288	1.115
Y_7	1.166	2.005	1.830	1.193	0.942	0.942	1	1.213	1.050
Y_8	0.961	1.652	1.509	0.983	0.776	0.776	0.824	1	0.865
Y_9	1.111	1.910	1.743	1.136	0.897	0.897	0.952	1.156	1

TABLE 4. AHP analytic hierarchy process results.

Item	Feature vector	Weight value	Maximum eigenvalue	CI value
Y_1 Awareness	1.010	11.222%	9.000	0.000
Y_2 Loyalty	0.588	6.528%		
Y_3 Reputation	0.643	7.150%		
Y_4 Aesthetic-emotional	0.988	10.973%		
Y_5 Technical functions	1.251	13.895%		
Y_6 Utility value	1.251	13.895%		
Y_7 Price level	1.178	13.087%		
Y_8 Channel convenience	0.971	10.786%		
Y_9 After-sales services	1.122	12.465%		

TABLE 5. Consistency check results.

Nth-order	3	4	5	6	7	8	9	10
RI value	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

Generally speaking, if the CR value is, the judgment matrix satisfies the consistency test; if the CR value is greater than 0.1, the judgement matrix satisfies the consistency test; if the CR value is greater than 0.1, it means that there is no consistency, and it should be adjusted appropriately after the judgement matrix is analyzed again. In this case, the CI value is 0.000 for the 7th order judgement matrix, and the RI value is 1.360, so the CR value is 0.000<0.1, which means that the judgement matrix satisfies the consistency test, and the weights obtained from the calculation are consistent, as shown in table 6.

TABLE 6. Summary of consistency check results.

Maximum characteristic root	CI value	RI value	CR value	Consistency check results
9.000	0.000	1.460	0.000	Passed

6) RELIABILITY AND VALIDITY TESTING OF EVALUATION MODELS

Correlation analysis was used to measure whether two variables were correlated or independent, and Pearson's correlation analysis was used to verify the independence of the indices. It is generally believed that a Pearson correlation coefficient greater than 0.8 means that the two variables have a high correlation and should be modified. This study was conducted on real users of smart homes in 31 provinces across China, 1,518 valid samples were collected, and the questionnaire data were analyzed using SPSS 25.0. The results show that the Pearson correlation coefficients of the 23 third-level indicators are less than 0.8, proving that the indicators have good independence.

Researchers often conduct reliability analyses to determine their dependability to ensure the reliability of sample data [44], [45], [46]. Internal consistency tests are typically performed to verify the uniformity of measured items. The Cronbach's alpha coefficient is a commonly used indicator to assess the scale's reliability. If the coefficient (denoted as ''a'') exceeded 0.8, it signified a high level of consistency and reliability, rendering the scale usable. Conversely, if ''a'' falls below 0.6, it indicates inadequate reliability, necessitating modifications to the questionnaire items. In this study, the ''Smart Home User Experience Evaluation Questionnaire'' data is analyzed using SPSS 25.0, yielding a coefficient of 0.987, which suggests a high level of reliability for the evaluation model.

Validity analysis aimed to examine the reasonableness of the scale's item design. Factor analysis was employed to test the structural validity of the evaluation system. Using SPSS 25.0, an exploratory factor analysis was conducted on the 23 indicators derived from the questionnaire. The Kaiser-Meyer-Olkin (KMO) value of 0.803 surpasses the threshold of 0.6, and the significance level of Bartlett's test of sphericity was less than 0.05, validating the suitability of this analysis method. Analyzing the 23 questions and their corresponding 23 items, the cumulative ANOVA reached 75.732%, indicating sound correspondence between the questions and factors. Furthermore, all the factor loadings for the 23 question items exceeded 0.5. Hence, it can be concluded that the evaluation model successfully passed the validity test, thus demonstrating robust validity.

IV. APPLICATION OF ASSESSMENT MODELS AND STANDARDISED PROCESS DESIGN

A. ANALYSIS OF THE OVERALL COMPETITIVENESS OF ENTERPRISES EVALUATING DATA

1) ENTERPRISE GRADIENT PERFORMANCE

Hardware enterprises excel in brand power, product power, and marketing power, and are characterized as all-rounders. Traditional home appliance manufacturers, Internet companies, communications carriers, and pendant companies need to promote brand building in the smart home sector, strengthen product power building, and promote digital transformation and whole-house intelligent layouts, as shown in table 7.

TABLE 7. Typical enterprise rankings and tiers.

Typical Enterprise	Total scores[a]
Xiaomi	81.8
Huawei	77.2
Midea	76.6
Haier	76.3
Baidu	75.9
Alibaba	73.4
GREE	71.9
China Telecom	70.3
China Mobile	69.7
China Unicom	68.2

[a]Total scores = Y1 * X1+ Y2 * X2 + Y3 * X3 + Y4 * X4 + Y5 * X5 + Y6 * X6 + Y7 * X7 + Y8 * X8 + Y9 * X9

The first echelons of enterprises in terms of brand power, product power, and marketing power index performance are very bright and relatively balanced. Enterprises in the first echelon of the industry include Haier, a traditional home appliance enterprise that entered the market early and deployed early, plowed deep into the industry, and successfully transformed, and Xiaomi and Huawei, which entered the market relatively late but deployed in all categories and focused on building product ecology. These enterprises have always paid great attention to brand building and marketing promotion [47]. Through continuous innovation and

optimization of products, services, and marketing strategies, they have continuously improved their brand competitiveness and user satisfaction.

In addition to the aforementioned all-round players, EZVIZ, Imou, and other enterprises in vertical market performance are very prominent. By focusing on products and services in specific areas, digging deep into user needs and pain points, building the value and reputation of pendant products, and plowing deep into hardware, these companies have successfully achieved a track breakout in the pendant market where their advantages are highlighted. In comparison, their overall competitiveness index is weak, and under the trend of smart home smart single products to whole-house smart development, it is an inevitable trend to transform the direction of the whole category in the future.

2) COMPETITIVE ANALYSIS OF VARIOUS TYPES OF ENTERPRISES

Firstly, enterprise brand power is an important element for enterprises to win users' trust and reputation in the market.hardware enterprises have invested a lot in brand building and have a high reputation and popularity in the market. Second, product power is the core of the enterprise to obtain a competitive advantage in the market, hardware enterprises in the product research and development and innovation of huge investments, and constantly improve product performance and user experience. Finally, marketing power is an important means by which enterprises can promote their products and services and attract users.

From the perspective of enterprise type, hardware enterprises are all-round players, leading the industry. The brand power, product power, and marketing power of enterprises are key elements for enterprises to continue to lead in market competition, and the performance of brand power, product power, and marketing power of IT science and technology enterprises are all at the leading level of the industry, with no obvious short boards.

Traditional home appliance manufacturers and pendant enterprises have relatively outstanding product power performance, especially the former's strong product power index, but they need to strengthen brand building in the smart home sector. These companies have strong advantages in product development, production, and supply chains; however, their brand building in the smart home sector is relatively weak, and they need to strengthen their brand promotion and marketing services.

Among Internet companies, Baidu is more eye-catching, with good performance in both product and marketing power. Baidu, in the search engine, intelligent hardware, Internet finance, and other areas of extensive layout, and in the product innovation and marketing and promotion of outstanding performance, for its in the field of smart home to win user reputation and market share laid a solid foundation.

The marketing power of communication operators is recognized by users, and brand and product power must be strengthened. Operators have a natural network advantage and control the core gateway products, but they are slightly insufficient in brand building and product innovation in the field of smart homes, and they need to strengthen their branding strategy and product innovation to enhance their market competitiveness [48].

To sum up, hardware enterprises excel in brand power, product power, and marketing power, featuring all-rounders and leading the entire industry. Traditional home appliance manufacturers, Internet companies, communication carriers, and pendant companies need to promote brand building in the smart home field, strengthen product power building, and promote digital transformation and whole-house intelligent layouts to construct long-term competitive advantages and achieve sustainable development, as shown in table 8.

TABLE 8. Competitiveness performance of various types of enterprises.

Enterprise	Brand Power Index	Product Power Index	Marketing Power Index
Xiaomi	95.0	81.5	73.1
Huawei	75.5	82.0	73.3
Midea	75.2	82.2	71.5
Haier	71.8	82.6	72.7
Gree	59.1	80.2	71.7
Baidu	74.1	79.9	72.8
Alibaba	66.1	80.7	70.5
China Telecom	52.7	80.5	71.4
China Mobile	52.3	79.4	71.3
China Unicom	45.7	79.9	71.1
EZVIZ	39.3	78.1	72.6
Imou	35.2	77.8	70.9

B. COMPETITIVENESS ANALYSIS OF ENTERPRISE SUBSECTORS OF EVALUATION DATA

1) BRAND POWER INDEX ASSESSMENT RESULTS

The brand power index includes three aspects: brand awareness, loyalty, and reputation.

Brand awareness varies widely among the enterprises. Enterprises should establish product brands early to help capture the minds of users, such as "Mejia" and "Haier Zhijuan," which are familiar to consumers. In addition, it is also important to effectively communicate the brand to users; thus, improving user awareness and memory is the core key to brand operation.

From the data, most companies have brand loyalty scores between 30 and 70, with Xiaomi performing the best with a brand loyalty score of 100. As there is still the problem of not being able to interconnect different brands, Xiaomi creates competitive barriers with its ecology and agreements to provide a full range of products. Once a consumer purchases a particular product, the probability of subsequent purchases of the same brand is higher in the absence of an obvious poor experience [49].

The level of brand reputation is similar across the companies. Consumers have a certain level of goodwill and trust in their brand. This indicates that from the perspective of spreading user fission word-of-mouth, competitors in the

TABLE 9. Performance of sub indicators of enterprise brand power.

Enterprise	Brand Power Index[b]	Sub Indicators		
		Awareness	Loyalty	Reputation
Xiaomi	95.0	100.0	100.0	82.6
Huawei	75.5	80.0	60.7	82.0
Midea	75.2	80.9	61.3	79.0
Baidu	74.1	80.4	57.2	79.7
Haier	71.8	73.9	59.6	79.6
Alibaba	66.1	67.4	49.3	79.4
GREE	59.1	55.9	43.4	78.7
China Telecom	52.7	47.9	34.4	76.8
China Mobile	52.3	47.9	31.4	78.1
China Unicom	45.7	38.4	26.4	74.8
EZVIZ	39.3	26.2	24.6	73.4
Imou	35.2	20.0	21.4	71.8

[b]Brand Power Index = (Y1 * X1 + Y2 * X2 + Y3 * X3) / (X1 + X2 + X3)

TABLE 10. Performance of sub indicators of enterprise product power.

Enterprise	Brand Power Index[c]	Sub Indicators		
		Awareness	Loyalty	Reputation
Xiaomi	95.0	100.0	100.0	82.6
Huawei	75.5	80.0	60.7	82.0
Midea	75.2	80.9	61.3	79.0
Baidu	74.1	80.4	57.2	79.7
Haier	71.8	73.9	59.6	79.6
Alibaba	66.1	67.4	49.3	79.4
GREE	59.1	55.9	43.4	78.7
China Telecom	52.7	47.9	34.4	76.8
China Mobile	52.3	47.9	31.4	78.1
China Unicom	45.7	38.4	26.4	74.8
EZVIZ	39.3	26.2	24.6	73.4
Imou	35.2	20.0	21.4	71.8

[c]Product Power Index = (Y4 × X4 + Y5 × X5 + Y6 × X6) / (X4 + X5 + X6)

industry present a similar pattern and enjoy a brand reputation with little difference, as shown in table 9.

2) PRODUCTIVITY INDEX EVALUATION RESULTS

The degree of difference in the overall product power index of each enterprise was not large, as shown in table 10. In terms of disaggregating the specific sub-indicators, there is no difference in aesthetic emotion and utility value, while the technical function is relatively large, which is the core influence element of the enterprise's product power to win.

Users' satisfaction with the aesthetic and emotional indicators of the product had the highest score, and the industry as a whole performed well. With the improvement of the material production level and the aesthetics of consumer groups, the value economy that is pleasing to the eye and pleasing to the heart has gradually become the new driving force of consumption [50]. Smart home products not only have both functional attributes, but also need to be matched with the style of home decoration, and can even be a decorative item; therefore, manufacturers pay more attention to meet the user's appearance needs when designing products.

TABLE 11. Performance of sub indicators of enterprise marketing power.

Enterprise	Brand Power Index[c]	Sub Indicators		
		Awareness	Loyalty	Reputation
Xiaomi	95.0	100.0	100.0	82.6
Huawei	75.5	80.0	60.7	82.0
Midea	75.2	80.9	61.3	79.0
Baidu	74.1	80.4	57.2	79.7
Haier	71.8	73.9	59.6	79.6
Alibaba	66.1	67.4	49.3	79.4
GREE	59.1	55.9	43.4	78.7
China Telecom	52.7	47.9	34.4	76.8
China Mobile	52.3	47.9	31.4	78.1
China Unicom	45.7	38.4	26.4	74.8
EZVIZ	39.3	26.2	24.6	73.4
Imou	35.2	20.0	21.4	71.8

[d]Marketing Power Index = (Y7 × X7 + Y8 × X8 + Y9 × X9) / (X7 + X8 + X9)

3) EVALUATION RESULTS OF THE MARKETING POWER INDEX

The marketing power index includes price level, after-sales service, and channel convenience, and users are most concerned with the price factor. At the user experience level, the price level does not affect the evaluation of use, but it will have a crucial influence on the product purchase decision. At present, the overall price perception of the industry is high, and the satisfaction score is the lowest (48 points), forming a large psychological gap between users and restricting the overall market penetration of smart products.

The after-sales service includes three sub-indicators of smoothness, responsiveness, and fault repair power, in which there is not much difference in the market performance of each enterprise in terms of service smoothness. Huawei, Xiaomi, and Haier perform better in terms of service responsiveness, and Huawei, Xiaomi, Haier, and China Telecom perform better in terms of fault repair power, as shown in table 11.

Channel convenience includes two subindicators: channel diversity and ease of purchase. Head enterprises not only consider both online and offline channels but also rely on their own terminal sales system, and the user experience of online purchase and delivery processes is better designed.

C. ANALYSIS OF EVALUATION RESULTS BY CATEGORY

From the perspective of scene maturity, the current smart home appliance scene has the highest maturity and the healthy life scene has the lowest maturity. From the user evaluation data of various categories of products, it was found that the maturity of intelligent home appliances and security monitoring scenes that meet the basic needs of users is high, followed by intelligent light sensing scenes, which need to be further cultivated, in which intelligent sensors with high product satisfaction and demand fulfilment can be used as the first breakthrough of key products.

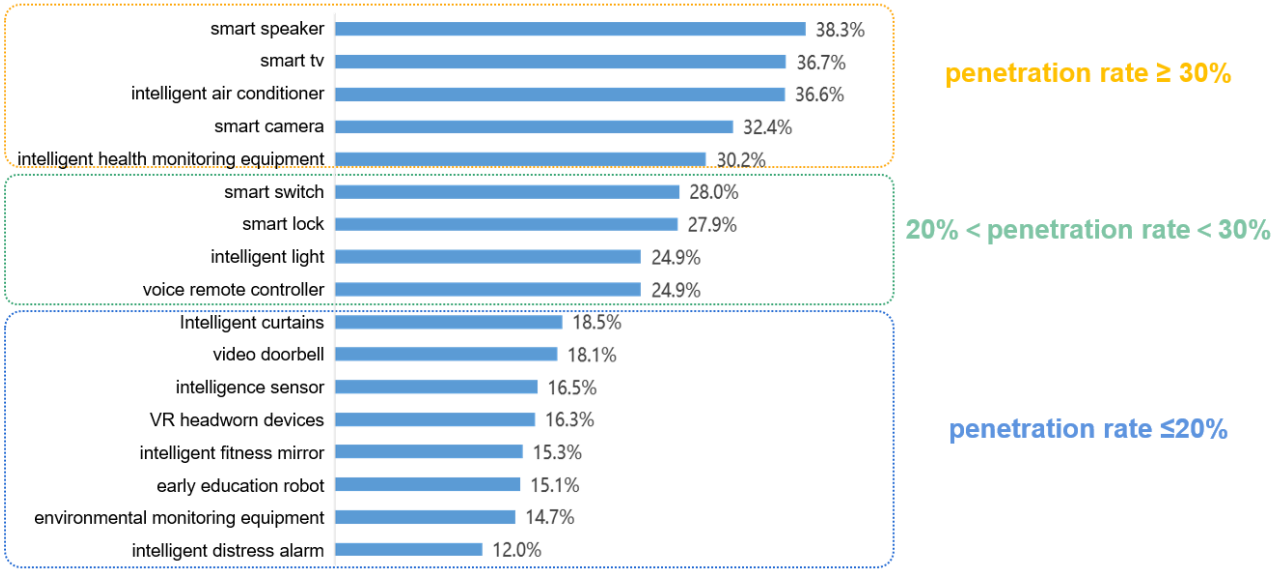

FIGURE 8. Market penetration rate of main products.

In terms of category penetration, smart speakers, smart TVs, smart air conditioners, smart cameras, and intelligent health-monitoring devices have the highest market penetration rates, all above 30%. Therefore, in terms of the selection of sales categories, enterprises should focus on mature consumer scenarios represented by smart home appliances and security monitoring and select high-penetration categories represented by smart speakers, smart TVs, smart air conditioners, smart cameras, and smart health monitoring devices, which is conducive to improving the overall sales conversion efficiency, as shown in figure 8.

D. STANDARDISED PROCESS DESIGN

Aiming at 12 representative companies and 17 key product categories in the smart home industry, real users were first recruited to process the data on the nine secondary indicator scores. After pre-testing, this questionnaire took about 100 to 300 seconds to answer the questions carefully, so sample data with less than 100 seconds of response time should be excluded. Next, the mean of each secondary indicator was calculated as well as the secondary indicator score for each business. The score of each enterprise's Level 2 indicator was compared to the average score. Indicators with scores higher than the average indicate that their performance is acceptable and should be maintained; those with scores lower than the average indicate that they do not perform well, and the corresponding indicators need to be described, deficiencies identified, and corresponding improvements made to improve user experience. Then, the nine second-level indicators are weighted to obtain the score of the first-level indicators of each enterprise, and then to obtain the overall evaluation score of each enterprise. Finally, each enterprise was ranked from highest to lowest based on their overall evaluation scores, as shown in figure 9.

V. DISCUSSION

There are four innovations in this study: First, this paper starts from the current hot issues of digital China construction [51] and focuses on the smart home business from a more micro perspective. Existing studies have mostly constructed evaluation indexes from macro perspectives, such as enterprise user scale [52], [53], market entry time [54], and breadth of category coverage, but lack micro user experience perspectives. With the increasing number of market participants and the increasing severity of product homogenization [55], user experience has become another factor that affects enterprise competitiveness. On this basis, the ''smart home business competitiveness evaluation system'' is proposed from the user perspective, which improves the evaluation perspective and expands the evaluation dimensions. This study addresses several key aspects of the evaluation of smart-home business competitiveness. First, it divides user research dimensions and organizes an evaluation system for both domestic and international contexts. From a long-term user experience perspective, an evaluation model was proposed across three dimensions: ''brand power,'' ''marketing power,'' and ''product power.''

This comprehensive analysis assesses the evaluation elements that impact a user's entire life-cycle experience. As a result, it enriches and advances the theoretical framework for evaluating smart home business competitiveness and combines the verification of statistical significance with practical applications. Through empirical research on the evaluation model, it was discovered that the model effectively quantified product indicators and industry participants' competitiveness.

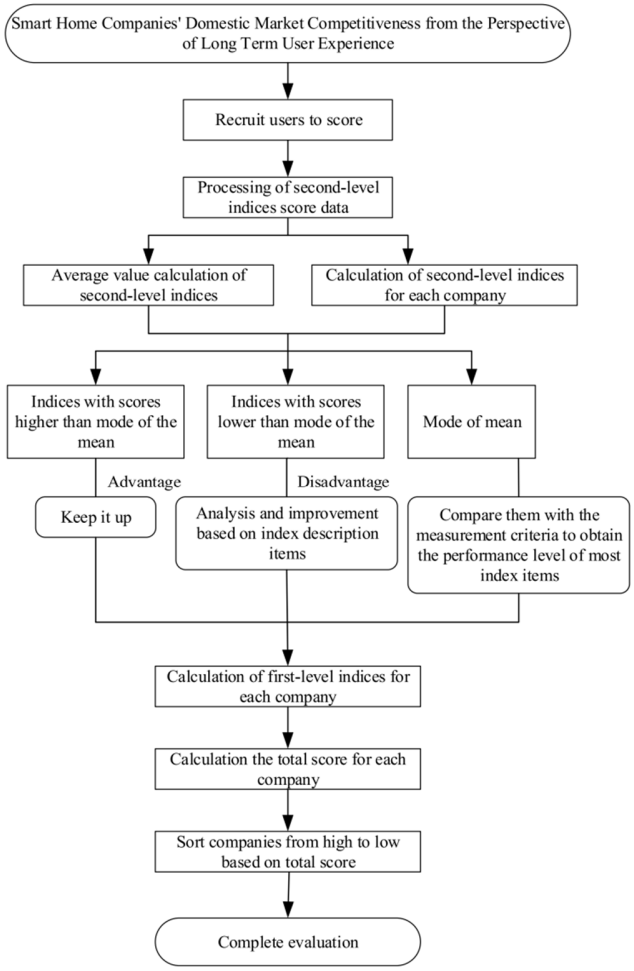

FIGURE 9. Standardization flowchart of evaluation system application.

Additionally, this study establishes a comparative analysis model for enterprises and products, providing valuable insights for enterprises to identify areas of improvement and enhance their user experience. By comparing scores from top to bottom, relative strengths and weaknesses can be derived, aiding enterprises in strategic adjustments and optimization. Furthermore, it facilitates product enhancement and optimization.To summarize, this study contributes to the theoretical system of evaluating smart home business competitiveness by proposing a comprehensive evaluation model, combining statistical verification with practical implementation, and establishing a comparative analysis framework for enterprises and products.

However, this study had some shortcomings. First, only the current year's data are available, and there is a lack of comparative analysis of the cyclical data. This study for the first time carried out a comprehensive assessment of the typical scenes and core categories of smart homes; however, due to the lack of comparison of the cycle data of the previous year, it is difficult to accurately judge the trend of the evolution of the product and the direction of change, and it is necessary to follow up the study to carry out cyclical and continuous tracking and to gain insights into and track the trend of the change in the business model of the smart home and the scenes of the categories through a longitudinal comparison of the time dimension. Second, the sample size of the application analysis was relatively small, and the comparative analysis only uses twelve companies and 17 categories for verification. Its applicability to larger samples and more categories of applications needs to be further explored and verified to reflect the full picture of China's smart home market in a more comprehensive and detailed manner. In addition, in countries and regions with better smart home development, there may be more linkages and interactions between their products [56], [57] to satisfy smarter and more convenient lifestyles, and these will also bring more dimensions and criteria for user experience evaluation. Therefore, the study of the user experience of smart home services for different products is a worthwhile issue that can be explored in future research.

VI. CONCLUSION

This paper combs through a large number of existing studies, summarizes the current research direction and background of smart home user experience evaluation, expands the evaluation perspective and evaluation dimensions on the basis of the existing evaluation methods in the industry, expands the user experience cyclic cycle model based on the long-term experience perspective, and expands the user experience cyclic cycle model from the three dimensions of branding power, product power, and marketing power, which compensates for the shortcomings of the existing evaluation methods in the three aspects of evaluation perspective, evaluation dimensions, evaluation quantification, and so on. This compensates for the shortcomings of existing assessment methods in terms of perspective, dimension, and quantification. At the same time, the Delphi method and AHP hierarchical analysis method were used to comprehensively evaluate the nine secondary indicators, and it was found that the first-level indicator ''product power'' and the second-level indicator ''technical function'' were the most important indicators affecting the user experience of smart home products. In addition, the user experience evaluation model of smart home competitiveness is constructed, user evaluation data are collected, 12 enterprises and 17 categories are put under the framework of user experience, and real first-hand information of user experience is obtained through user evaluation and scoring; thus, it can be concluded that the evaluation model has good reliability and validity in a statistical sense, and it has practical value in practical applications.

The smart-home competitiveness index assessment model constructed in this study is scalable. The data basis of this assessment model is the structured data of smart home product user experience, which is not only applicable to the quantitative assessment of the competitiveness of each enterprise in the smart home industry, but also to the single product assessment and product comparative assessment, which provides a more detailed quantitative method for the analysis of

product competition. Therefore, the model has a wide range of practical applications.

The smart home industry has flourished under the support of national policies, and has rapidly completed large-scale popularization and promotion. Its advantages in terms of safety and intelligence have been widely recognized compared with traditional home products. With the popularization of digital life intelligence and the concept of creating future-oriented intelligent immersive service experiences, in the future, smart homes are expected to become an important part of constructing a new picture of a better digital life. However, research on the evaluation of smart home user experience quality is still in progress.

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