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SMART HOME CONSUMER NEEDS BASED ON K-MEANS CLUSTERING AND KANO MODEL

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Abstract: With the rapid development and market expansion of smart home technology, the diversification and differentiation of consumer needs have become increasingly prominent. Based on survey data from 431 consumers, this study employs the K-means clustering algorithm to segment smart home consumers, using the silhouette coefficient method to determine the optimal number of clusters as 4, dividing consumers into bottom-tier frugal, middle-class pleasure-seeking, upper-middle comfort-seeking, and high-net-worth groups. The research further analyzes consumer need characteristics using the KANO model, identifying home security and product appropriateness as must-be attributes, entertainment and media control and installation services as expected attributes, and product reputation as an attractive attribute. The results indicate that smart home consumers across different income and age levels exhibit distinctly different need characteristics and purchasing power, while product safety and appropriateness remain fundamental needs across all groups. This research provides data support and theoretical guidance for smart home product development and marketing strategies, offering practical significance for promoting the healthy development of the smart home industry.
Keywords: K-means clustering; Smart home; KANO model; Consumer needs

1 INTRODUCTION

With the rapid advancement of information technology and the Internet of Things, smart home technology is gradually becoming mainstream as a new lifestyle, serving as an important means to enhance residential comfort, security, and convenience[1, 2]. Smart home technology integrates various devices and systems within the home environment to achieve automated control and intelligent management, creating a smarter and more efficient living environment for users[3]. However, the current smart home market presents a situation where products are diverse but user needs remain unclear. On one hand, the market offers a wide variety of smart home products with different functions and price ranges; on the other hand, consumer groups exhibit significant heterogeneity, with different populations showing marked differences in purchasing power, technology acceptance, and usage requirements. This disconnect between product supply and consumer demand has led to problems such as low market penetration and insufficient user satisfaction, hindering the healthy development of the smart home industry. Therefore, gaining an in-depth understanding of the characteristics and needs of different consumer groups to achieve precise product development and marketing strategies is of great significance for promoting the development of the smart home industry.

To address these issues, this study employs the K-means clustering algorithm to analyze 431 survey respondents, categorizing smart home consumers into four typical groups: the bottom-tier frugal group, the middle-class pleasure-seeking group, the upper-middle comfort-seeking group, and the high-net-worth group. The research identifies significant differences among these groups in terms of purchase intention, acceptable price range, gender, age, and income. Further, the study applies the KANO model to analyze the core needs of each group, classifying them into must-be attributes, expected attributes, attractive attributes, and indifferent attributes, and proposes priority recommendations for product development. These findings help smart home companies understand consumers' diverse needs, develop differentiated products, and implement precise marketing strategies, promoting the deep integration of smart home technology with users' actual needs.

2 CONSUMER SEGMENTATION ANALYSIS OF SMART HOME USERS BASED ON K-MEANS CLUSTERING

The K-means algorithm, also known as k-means clustering, is a partition-based clustering method. It divides 431 survey respondents into distinct groups, with each group named to provide an intuitive summary of participant profiles and characteristics, ultimately enabling better service to these populations.

The K-means clustering model segments consumers of smart home technology. The dataset consists of 431 user samples, each containing 11 attributes: smart home device usage status, smart home product purchase history, acceptable purchase price range for smart home devices, gender, age, annual household income, living situation, educational background, occupation, purchasing channels, and conceptual understanding of smart home technology. The number of clusters is assumed to be K.

The process involves selecting a k value, then iteratively calculating distances and centroids until meeting termination conditions, thereby determining the optimal solution. The K-means clustering algorithm operates on the principle of first initializing K cluster centers, then classifying samples into clusters based on the calculated distance between

samples and center points. Through iteration, it achieves the objective of minimizing the distance between samples and their assigned cluster centers.

$$arg\ min\ J(C) = \sum_{k=1}^{K} \sum_{x^{(i)} \in C_k} ||x^{(i)} - \mu^{(k)}||\ _2^2 \quad (1)$$

The quality of clustering results can be evaluated using the "silhouette coefficient method." The core metric of this method is the silhouette coefficient. For a given sample point Xi, the silhouette coefficient is defined as follows:

$$S(X_i) = \frac{b(i) - a(i)}{max\{a(i), b(i)\}} \quad (2)$$

where a(i) = average, known as the cohesion, and b(i) = min, known as the separation. The silhouette coefficient value ranges between [-1,1], with values closer to 1 indicating relatively optimal levels of both internal cohesion and separation between clusters.

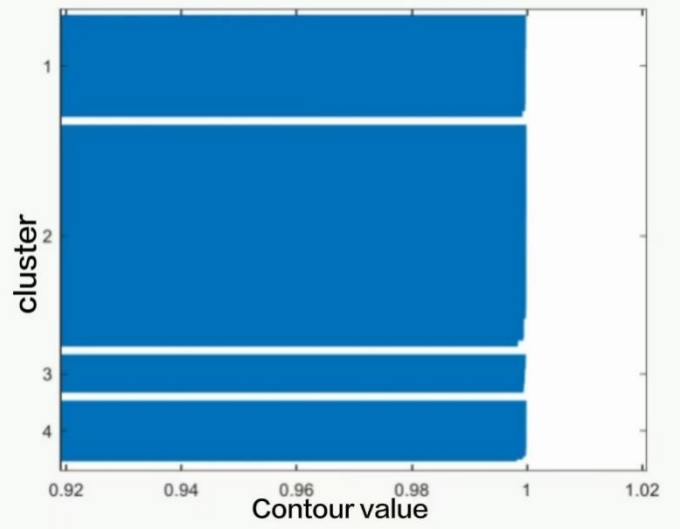

Figure 1 Silhouette Value Analysis Chart

This paper employs the "silhouette coefficient method" to analyze the data using MATLAB, generating visual representations. As shown in the figure 1, the silhouette values are concentrated around 1, indicating that a cohesion value of 4 is scientifically appropriate for this dataset and yields optimal partitioning quality.

In the implementation of K-means using MATLAB with K value set to 4, iterative and cluster analysis was performed using SPSS software based on 11 factors: whether smart home devices are used, whether smart home devices are purchased, acceptable price range for smart home devices, gender, age, annual household income, living status, education level, occupation, purchasing channels, and concept understanding. As shown in Table 1.

Table 1 One-way analysis of variance table

Variable	Cluster (Mean Square)	df (Cluster)	Error (Mean Square)	df (Error)	F	Sig. (p-value)
Willingness to Buy	0.487	3	0.080	427	6.118	.000
Purchase Amount	1127243619.490	3	0.000	427	—	—
Gender	1.084	3	0.224	427	4.834	.003
Age	1465.810	3	76.748	427	19.099	.000
Annual Income	14490.590	3	516.975	427	28.030	.000
Living Status	5.214	3	0.900	427	5.795	.001
Education Level	1.209	3	0.553	427	2.187	.089
Occupation	37.364	3	9.248	427	4.040	.007
Purchase Channel	3.393	3	0.808	427	4.199	.006
Awareness	4.243	3	0.625	427	6.789	.000
Usage	0.475	3	0.194	427	2.446	.063

From the ANOVA (one-way analysis of variance) output generated by SPSS, it can be seen that both education level and whether smart home devices are used exceeded 0.05, indicating that these two indicators have minimal impact on clustering and can be eliminated. Therefore, nine factors were ultimately selected as new clustering measurement factors: whether smart home devices are purchased, acceptable price range for smart home devices, gender, age, annual household income, living status, occupation, purchasing channels, and understanding of smart home concepts.

Based on the clustering results above, we have categorized smart home consumers into four distinct groups:

The bottom-tier frugal group represents approximately 10% of the total population. This demographic shows relatively low purchase intention for smart home products and is predominantly female. They are willing to spend less than 1,000 yuan on smart home devices, with ages typically between 20-30 years old and annual incomes below 120,000 yuan. Most live alone or with one other person and work as ordinary employees. Their purchasing pattern involves examining products in physical stores first before buying online, and their understanding of smart home technology is relatively limited.

The middle-class pleasure-seeking group accounts for about 59% of the total population and contains the majority of survey respondents. Predominantly female with high purchase intention, they are willing to spend between 1,000-5,000 yuan on smart home products. Their age range is primarily 20-30 years old, with household annual incomes between 120,000-300,000 yuan. Most live alone or with one other person and work as ordinary employees. Like the first group, they prefer to view products in physical stores before purchasing online. They possess moderate knowledge about smart home technology and tend to be young, quick to accept new things, and have some disposable income.

The upper-middle comfort-seeking group represents approximately 23% of the total population. This group is predominantly male with high purchase intention for smart home products and is willing to spend between 5,000-10,000 yuan. Their ages concentrate in the 30-40 range, skewing toward the early thirties, with household annual incomes ranging from 300,000-1,000,000 yuan. They typically work in corporate management positions and live in multi-person households. Their purchasing pattern mirrors the other groups—examining products in physical stores before buying online. Their understanding of smart home technology is high, and they tend to be well-educated.

The high-net-worth group makes up about 8% of the total population. They show high purchase intention for smart home products and are willing to spend over 10,000 yuan. Predominantly male, their ages concentrate in the 30-40 range, skewing toward the early forties, with household annual incomes typically above 500,000 yuan. Like other groups, they prefer examining products in physical stores before purchasing online. They possess extensive knowledge about smart home technology.

In summary, regardless of age group, people tend to approach smart home purchases rationally, generally choosing products with higher value for money. Similarly, smart home purchasing decisions align with individuals' economic circumstances—the better one's financial situation, the higher the acceptable spending threshold for smart home products. Among different age groups, younger people show a higher acceptance of smart home technology. Understanding these varying consumer needs allows businesses to design products at different price points with different features, thereby more effectively meeting market demands.

3 PRIORITY RESEARCH ON SMART HOME CONSUMER NEEDS BASED ON KANO MODEL

The KANO model, developed by Professor Noriaki Kano of Tokyo Institute of Technology, classifies and prioritizes user requirements by analyzing how these requirements impact user satisfaction, thereby establishing priorities for product feature upgrades[4-6]. Based on the relationship between different quality characteristics and customer satisfaction, the KANO model categorizes product and service quality characteristics into five types. The KANO model graph illustrates the developmental features of these five attributes:

In attractive attributes, high levels of service refinement lead to a significant increase in user satisfaction. Meanwhile, in one-dimensional attributes (expected attributes), high levels of service refinement result in increased user satisfaction; conversely, low levels lead to decreased satisfaction. For must-be attributes (basic attributes), high levels of service refinement do not significantly increase user satisfaction; however, low levels cause a marked decrease in satisfaction. Regarding indifferent attributes, there is no discernible relationship between service refinement and user satisfaction. Lastly, in reverse attributes, high levels of service refinement actually lead to decreased user satisfaction.

This research utilizes SPSSAU software, and the results show that: in terms of service provision priorities, the general sequence is: must-be attributes > expected attributes > attractive attributes > indifferent attributes[7-8].

Must-be attributes: Based on the KANO model results above, this study concludes that the essential requirements for potential consumers are home security and appropriate products. These two indicators are viewed as basic attributes and represent the highest priority needs. Only when these conditions are met in smart home products can the basic requirements of potential consumers be satisfied.

Expected attributes: Entertainment and media control, along with installation services, are expected attributes for potential smart home consumers. Having entertainment and media control capabilities and installation services significantly increases potential consumers' satisfaction with smart homes. Conversely, the absence of these features would decrease satisfaction among potential smart home consumers.

Attractive attributes: Product reputation is an attractive attribute; a good product reputation generates positive emotions in potential consumers. After ensuring entertainment and media control capabilities and installation services, manufacturers should consider enhancing product reputation and expanding brand awareness along with positive messaging, thereby further increasing consumer satisfaction with smart home products.

Indifferent attributes: Potential smart home consumers are indifferent to the experiential aspects of smart homes or whether they meet personalized needs. These are considered indifferent factors, and their presence or absence does not influence potential consumers' purchasing behavior at the current stage. Therefore, these have the lowest priority and can be developed last.

In conclusion, to better enhance consumer satisfaction with smart home products, this research suggests first ensuring the safety and appropriateness of smart home products. Next, the development of entertainment and media control features and improvement of installation services can significantly enhance consumers' experience and satisfaction with smart homes. Finally, improving smart home product reputation through consistent quality across every product and providing comprehensive services will maximize the potential to reach latent smart home consumers.

4 CONCLUSIONS

This study conducted an in-depth analysis of the smart home consumer market using the K-means clustering algorithm and KANO model. The research identified four distinct categories of smart home consumers: the bottom-tier frugal group (10%), middle-class pleasure-seeking group (59%), upper-middle comfort-seeking group (23%), and high-net-worth group (8%). These four groups showed significant differences in purchase intention, acceptable price range, age, income, and understanding of smart home technology.

The KANO model analysis indicated that smart home product development should prioritize satisfying basic attributes, specifically home security and product appropriateness. Next, expected attributes such as entertainment and media control features and installation services should be emphasized. Enhancing product reputation, as an attractive attribute, can further increase consumer satisfaction. Experience-related and personalized needs were identified as indifferent attributes that can be developed at later stages.

The findings provide clear market segmentation and product development guidance for smart home businesses, enabling them to design products with different price points and features more strategically to meet various consumer needs effectively and enhance market competitiveness. By understanding the diverse characteristics and priority order of consumer needs, smart home enterprises can achieve precise product positioning, optimize resource allocation, and ultimately achieve sustainable development.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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