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Study on the Factors Influencing Residential Building Air Conditioning Behavior Based on SEM

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Abstract: *With the rapid development of China's economy, the widespread adoption of air conditioning in residential areas has enhanced the comfort of residents but also led to increased energy consumption and environmental burden. This study utilizes Structural Equation Modeling (SEM) to analyze the impact of factors such as living environment, economic conditions, psychological tendencies, social influences, and cultural awareness on air conditioning behavior. The results indicate that living environment, economic conditions, and psychological tendencies significantly promote air conditioning usage, while social influences and cultural awareness effectively curb excessive use. Specifically, a good living environment reduces reliance on air conditioning, high income and low electricity prices encourage increased usage, and residents with strong environmental consciousness are more inclined to use air conditioning in an energy-efficient manner. Based on these findings, this study proposes strategies to improve the living environment, strengthen government policy incentives, promote energy-saving culture, and enhance social influences and individual behavior management, aiming to reduce energy consumption and emissions from air conditioning use, thus contributing to sustainable environmental development.*

Keywords: *Structural Equation Modeling, Air Conditioning Usage Behavior, Influencing Factors, Energy-saving Strategies*

1. Introduction

With the rapid development of China’s economy and the continuous improvement in the standard of living, public expectations for comfortable living environments have risen, and the requirements for building energy efficiency have become increasingly stringent. In recent years, frequent extreme heatwaves have significantly increased energy consumption in heating, ventilation, and air conditioning (HVAC) systems in residential buildings [1, 2].Among these, the widespread adoption of split air conditioner (SAC) in residential areas in China has improved the comfort of living environments to some extent but has also increased residents' reliance on air conditioning systems.

The use of split air conditioners exhibits diversity, randomness, and variability. Specifically, air conditioning behavior includes the operational modes employed by residents when using air conditioning, such as temperature settings, usage duration, switching habits, and usage frequency [3].Among these, temperature settings and usage duration are the two most widely studied core behaviors [3, 4], directly influencing energy consumption and carbon emissions [5]. Existing studies have shown that relying solely on policy interventions or technological measures to improve energy efficiency is insufficient to significantly curb the growth of energy consumption [6], as residents' behavior, a key factor influencing building energy use, is often overlooked [7, 8].

In response to the challenges of energy consumption and greenhouse gas emissions, the Chinese government issued the "Energy Conservation and Carbon Reduction Action Plan for 2024-2025" in 2024. This plan advocates for a dual approach of technological innovation and lifestyle optimization to achieve energy-saving and carbon-reduction goals. The plan emphasizes promoting green lifestyles from building energy-saving technologies to individual behavior guidance, aiming to achieve the sustainable development goal of harmonious coexistence between humans and nature. In this context, exploring the factors influencing air conditioning usage behavior and gaining a deeper understanding of the underlying reasons for residents' air conditioning behavior are of great significance for advancing the achievement of energy-saving and carbon-reduction targets.

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2. Research Methods.

2.1. Factors Influencing Air Conditioning Usage Behavior

Air conditioning usage behavior is a multidimensional and complex process, influenced by various factors. A comprehensive consideration of multiple aspects is necessary to gain an in-depth understanding of the underlying mechanisms. Existing research has identified the main manifestations of air conditioning usage behavior as temperature settings, usage duration, and frequency of use. Based on a systematic review of the literature, the factors influencing air conditioning usage behavior can be categorized into six major groups: individual differences, living environment, economic conditions, psychological tendencies, social influences, and cultural awareness, as shown in Table 1.

Table 1: Factors Influencing Air Conditioning Usage Behavior.

Classification Dimension	Influencing Factors
Individual Differences	Gender [9], Age [9-12]
Living Environment	Housing type [11, 13], Housing insulation [11], Housing ventilation effectiveness [11]
Economic Conditions	Income satisfaction [11, 14, 15], Energy prices [11], Income pressure [11-13]
Psychological Tendencies	Preferences for temperature (hot/cold) [16], Air conditioning preferences [17, 18], Attitudes [17]
Social Influences	Opinions of others [18-20], Government policies [20], Social media [19, 20]
Cultural Awareness	Product knowledge [13], Educational level [12, 15], Energy-saving awareness [13]

2.2. Research Hypotheses

To assess the direct and indirect effects of living environment, economic conditions, psychological tendencies, social influences, and cultural awareness on air conditioning usage behavior, and to analyze the causal relationships and interactions among these factors, this study employs Structural Equation Modeling (SEM). Among the factors influencing air conditioning usage behavior, individual differences (gender and age) are included as control variables in the model. Based on the literature review, the following hypotheses are proposed:

H1: The living environment has a negative impact on air conditioning usage behavior.

The living environment directly affects an individual's air conditioning usage behavior. Climate characteristics influence the demand for air conditioning, especially in hot regions where users are more likely to use air conditioning. In addition, the insulation properties and ventilation effectiveness of housing also significantly affect the demand for air conditioning. For example, homes with better insulation reduce indoor temperature fluctuations, thereby decreasing the frequency of air conditioning use.

H2: Economic conditions have a positive impact on air conditioning usage behavior.

Economic conditions are key factors influencing an individual's decision to use air conditioning. Household income levels and energy prices significantly affect the frequency, duration, and temperature settings of air conditioning. Higher income levels or lower energy prices encourage individuals to use air conditioning more frequently, while lower income or higher energy prices may lead individuals to reduce their air conditioning use.

H3: Psychological tendencies have a significant positive impact on air conditioning usage behavior.

Psychological tendency factors reflect an individual's subjective attitude toward air conditioning usage. Air conditioning dependence and comfort preferences lead individuals to use air conditioning over a broader range of environmental temperatures, often setting the temperature lower and preferring higher comfort levels.

H4: Social influences have a positive impact on air conditioning usage behavior.

Social influence factors exert potential constraints on individual air conditioning usage behavior through the external environment. Opinions from family and friends, social media, and government policies may guide and regulate air conditioning usage behaviors, creating social constraints.

H5: Cultural awareness has a positive impact on air conditioning usage behavior.

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Cultural awareness reflects an individual's sense of environmental responsibility and recognition of sustainable development. Individuals with higher educational levels and stronger environmental consciousness are more likely to use air conditioning in a reasonable and energy-efficient manner.

2.3. Data Collection and Analysis

2.3.1. Questionnaire Collection

The survey was conducted using an online questionnaire, with the survey period from June 28, 2024, to August 24, 2024, lasting a total of 58 days. A total of 460 valid responses were collected. The questionnaire consisted of three sections: 1) Basic individual information (gender, age); 2) Air conditioning usage behavior (temperature settings, usage duration, frequency of use); 3) A scale of factors influencing air conditioning behavior (see Table 2), including living environment, economic conditions, psychological tendencies, social influences, and cultural awareness. All items were measured using a five-point Likert scale, where: 1 represents "Strongly disagree", 2 represents "Disagree", 3 represents "Neutral", 4 represents "Agree", and 5 represents "Strongly agree".

For air conditioning usage behavior, three indicators were coded. Specifically:

Air conditioning temperature setting: (16-18℃ = 1, 19-21℃ = 2, 22-24℃ = 3, 25-27℃ = 4, 28℃ and above = 5)

Air conditioning usage duration: (≤ 2 hours = 1, 2-6 hours = 2, 7-10 hours = 3, 11-14 hours = 4, > 14 hours = 5)

Air conditioning usage frequency: (Less than once a day = 1, 1-2 times a day = 2, 3-4 times a day = 3, Multiple times a day = 4, Continuous use all day = 5)

Table 2: Air Conditioning Behavior Influencing Factors Scale.

Latent Variable	Observed Variable	Measurement Item
Living Environment	S21	I am satisfied with the climate in my area during summer.
	S22	The ventilation of the house I live in is good.
	S23	The insulation performance of the house I live in is good.
Economic Condition	S31	I am highly satisfied with my family's income level.
	S32	I can easily afford the electricity costs for air conditioning in summer.
	S33	I have never restricted air conditioning use due to financial concerns.
Psychological Tendencies	S41	I prefer to use air conditioning to adjust indoor temperature.
	S42	I enjoy being in an air-conditioned environment.
	S43	I am highly dependent on air conditioning.
Social Influence	S51	The opinions of family members (or people around me) influence my air conditioning use.
	S52	Government policies (e.g., power restrictions, electricity fee adjustments) influence my air conditioning use.
	S53	Environmental and energy-saving campaigns on social media influence my air conditioning use.
Cultural Awareness	S61	I am aware of the potential negative environmental impact of air conditioning use.
	S62	My educational background has made me aware of the importance of energy-saving behavior.
	S63	I tend to choose air conditioners that have energy-saving labels.

2.3.2. Data Analysis Methods

This study uses SPSS and AMOS software for data analysis. The preliminary data analysis includes descriptive statistics and reliability testing. To verify the research hypotheses, Structural Equation Modeling (SEM) is employed to analyze the path relationships among the factors. The model fit is evaluated using several indicators, including the chi-square value (χ^2), degrees of freedom (df), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA).

3. Model Testing

3.1. Reliability and Validity Testing

This study first verifies the reliability and validity of the measurement model to ensure the data quality and the model's fit. The results are shown in Table 3. Reliability testing was conducted using Cronbach's α coefficient. The results indicate that the Cronbach's α values for all latent variables are above 0.7, and the mean Corrected Item-Total Correlation (CITC) values exceed 0.5, suggesting good internal consistency for the measurement items. Validity testing was carried out using Exploratory Factor Analysis (EFA), and the Composite Reliability (CR) values for all constructs are greater than 0.7, while the Average Variance Extracted (AVE) values are above 0.50, indicating that the research data has good validity.

Table 3: Reliability and Validity Test Results.

Latent Variable	Observed Variables	CITC	Standardized Loadings	S.E.	Cronbach's α	AVE	CR
AC Usage	S11	0.519	0.626	-	0.743	0.58	0.792
	S12	0.71	0.92	0.175			
	S13	0.535	0.634	0.129			
Living Environment	S21	0.789	0.856	-	0.897	0.744	0.897
	S22	0.815	0.886	0.043			
	S23	0.787	0.848	0.046			
Economic Conditions	S31	0.822	0.868	-	0.918	0.79	0.919
	S32	0.874	0.951	0.041			
	S33	0.809	0.847	0.044			
Psychological Tendencies	S41	0.693	0.762	-	0.867	0.697	0.872
	S42	0.754	0.839	0.07			
	S43	0.795	0.889	0.067			
Social Influence	S51	0.781	0.845	-	0.884	0.719	0.885
	S52	0.79	0.879	0.046			
	S53	0.754	0.818	0.046			
Cultural Awareness	S61	0.675	0.767	-	0.839	0.643	0.843
	S62	0.764	0.875	0.063			
	S63	0.668	0.758	0.059			

3.2. Structural Equation Model Analysis and Testing

The structural model was built using AMOS, and the path output results are shown in Figure 1 and Table 4. The model fit indices are provided in Table 5. The chi-square/df ratio, GFI, CFI, RMSEA, and other indices all meet the standard requirements, indicating that the structural model fits the data well. The specific details of the model paths are as follows:

Living Environment: The standardized path coefficient for living environment on air conditioning usage behavior is -0.172, indicating a significant negative effect ($p < 0.001$). This suggests that a better living environment significantly reduces air conditioning usage, whereas poorer insulation and ventilation conditions increase air conditioning usage.

Economic Conditions: The standardized path coefficient for economic conditions on air conditioning usage behavior is 0.183, also showing a significant positive effect ($p < 0.001$). This indicates that better economic conditions promote increased air conditioning usage, while lower economic conditions and higher financial burdens limit the frequency and duration of air conditioning usage. Users facing economic pressure tend to choose more energy-efficient usage patterns.

Psychological Tendencies: The standardized path coefficient for psychological tendencies on air conditioning usage behavior is 0.321, showing a significant positive effect ($p < 0.001$). This indicates that dependence on air conditioning and comfort preferences are the main drivers of air conditioning usage behavior, with individuals tending to use air conditioning more frequently and setting lower comfort temperatures.

Social Influence: The standardized path coefficient for social influence on air conditioning usage behavior is -0.307, showing a significant negative effect ($p < 0.001$). This suggests that policy advocacy, social media guidance, and opinions from surrounding individuals have a suppressive effect on air conditioning usage decisions, indicating that social factors can effectively reduce air conditioning usage.

Cultural Awareness: The standardized path coefficient for cultural awareness on air conditioning usage behavior is 0.199, showing a positive effect ($p < 0.01$). This indicates that users with strong environmental and energy-saving awareness are more likely to use air conditioning in a rational and moderate way to achieve energy-saving and environmental protection goals.

Gender: The standardized path coefficient for gender on air conditioning usage behavior is -0.077, which is not statistically significant ($p = 0.084$). This suggests that gender does not have a significant impact on air conditioning usage behavior in this study.

Age: The standardized path coefficient for age on air conditioning usage behavior is -0.156, showing a significant negative effect ($p < 0.001$). This indicates that older individuals tend to use air conditioning less intensively.

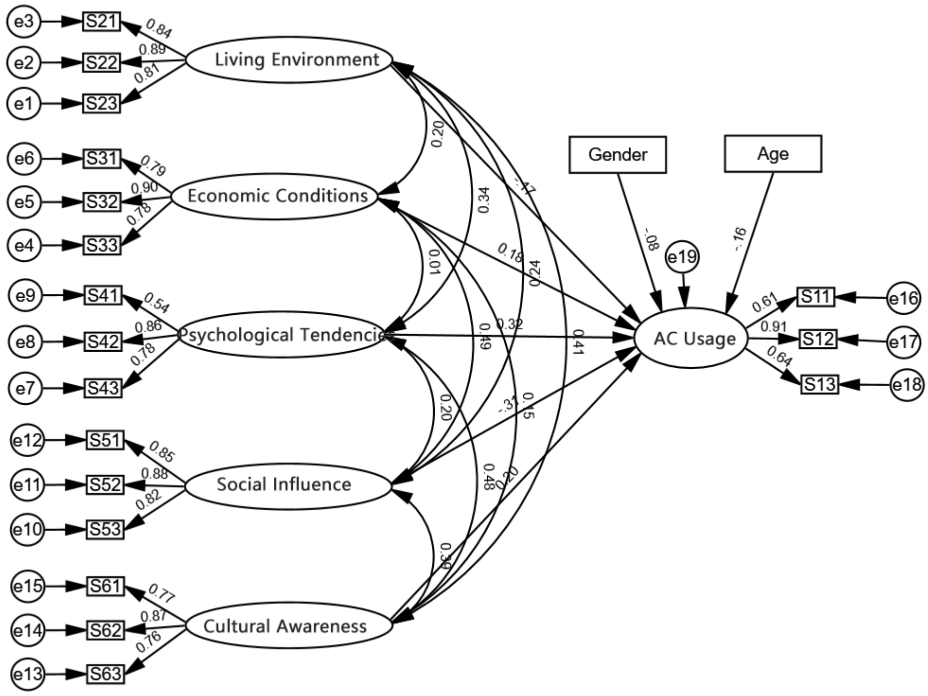

Figure 1: Structural Equation Model Diagram.

Table 4: Model Regression Coefficients.

Hypothesis	Path	Unstandardized Coeff.	Standardized Coeff.	Standard Error	C.R.	P
H1	Living Environment → AC Usage	-0.09	-0.172	0.029	-3.065	0.000***
H2	Economic Conditions → AC Usage	0.088	0.183	0.029	3.087	0.000***
H3	Psychological Tendencies → AC Usage	0.16	0.321	0.033	4.932	0.000***
H4	Social Influence → AC Usage	-0.156	-0.307	0.034	-4.639	0.000***
H5	Cultural Awareness → AC Usage	0.118	0.199	0.039	2.992	0.000***
H6	Gender → AC Usage	-0.072	-0.077	0.042	-1.728	0.084
H7	Age → AC Usage	-0.049	-0.156	0.014	-3.443	0.000***

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Table 5: Model Fit Indices.

Common Indices	X^2	df	Chi-square/df	GFI	RMSEA	CFI	NFI	NNFI
Threshold Values	-	-	<3	>0.9	<0.10	>0.9	>0.9	>0.9
Results	297.194	120	2.477	0.941	0.057	0.964	0.941	0.953

The covariance relationships among the model path nodes are shown in Table 6, revealing significant associations between living environment, economic conditions, psychological tendencies, social influence, and cultural awareness. The following key points can be derived from the results:

Living Environment: It is positively correlated with economic conditions, psychological tendencies, social influence, and cultural awareness, with the strongest correlation being with cultural awareness (standardized coefficient = 0.407). This suggests that users in better living environments tend to have higher energy-saving awareness and environmental consciousness.

Economic Conditions: It shows a positive correlation with social influence and cultural awareness, indicating that individuals in better economic conditions are more likely to be influenced by others' opinions and policy guidance, and are more focused on environmental consciousness.

Psychological Tendencies: It is positively correlated with social influence and cultural awareness, with the strongest relationship observed with cultural awareness (standardized coefficient = 0.484). This suggests that air conditioning dependence and comfort preferences are strongly associated with environmental awareness.

Social Influence and Cultural Awareness: The strong correlation between social influence and cultural awareness (standardized coefficient = 0.394) further indicates that policy guidance and social media impact can enhance users' energy-saving awareness.

These covariance relationships suggest that there are complex interactions between latent variables, which jointly influence users' air conditioning behavior, providing in-depth theoretical support for understanding the underlying factors.

Table 6: Path Node Covariance Relationships.

Path	Unstandardized Coeff.	Standardized Coeff.	Standard Error	P
Living Environment → Economic Conditions	0.18	0.205	0.048	0.000***
Living Environment → Psychological Tendencies	0.285	0.336	0.051	0.000***
Living Environment → Social Influence	0.197	0.236	0.046	0.000***
Living Environment → Cultural Awareness	0.292	0.407	0.044	0.000***
Economic Conditions → Psychological Tendencies	0.008	0.009	0.05	0.875
Economic Conditions → Social Influence	0.439	0.488	0.056	0.000***
Economic Conditions → Cultural Awareness	0.112	0.145	0.042	0.008
Psychological Tendencies → Social Influence	0.176	0.202	0.049	0.000***
Psychological Tendencies → Cultural Awareness	0.363	0.484	0.05	0.000***
Social Influence → Cultural Awareness	0.29	0.394	0.044	0.000***

4. Conclusion

Based on the findings of this study, the following strategies are proposed to optimize air conditioning (AC) usage behavior in order to achieve energy conservation, emission reduction, and enhance environmental sustainability:

Improving the Living Environment: To reduce excessive reliance on air conditioning, it is essential to enhance the comfort of living environments. Governments and enterprises should encourage the

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adoption of energy-efficient building designs that improve insulation and ventilation, especially in areas with poor airflow. Promoting green building technologies and using high-efficiency, energy-saving materials not only increases residential comfort but also reduces the demand for air conditioning.

Government Policies and Incentives: The government can support the widespread adoption of energy-efficient air conditioners through policy incentives. For example, subsidies or tax breaks for purchasing energy-efficient air conditioning units can encourage consumers to select higher-efficiency models. At the same time, the government should strengthen industry regulation, establish more stringent energy efficiency standards, and drive the market toward environmentally friendly air conditioning products. The promotion of smart air conditioning technology, which optimizes energy use by automatically adjusting temperature settings and usage duration, is also essential to improving the overall efficiency of air conditioning systems.

Energy Conservation Awareness and Cultural Advocacy: Strengthening residents' awareness of energy conservation is crucial to improving the energy efficiency of air conditioning usage. The government, media, and businesses should enhance energy-saving campaigns through social media, advertising, and other channels to educate the public about the proper use of air conditioning. Advocating for setting appropriate temperatures and reducing the frequency of AC use will help create a culture of energy efficiency. Through education and guidance, a more energy-conscious and environmentally-friendly social atmosphere can be cultivated.

Social Influence and Community Guidance: Social behavior has a significant impact on individual actions, and therefore, community-based efforts, social media, and neighborhood networks can guide residents to adopt more energy-efficient AC usage patterns. For example, communities can organize energy-saving workshops, encourage residents to participate in energy-saving activities, and use role models to influence behavior changes. Social media platforms can also play a role by promoting energy-efficient air conditioning practices and encouraging broader participation in energy conservation actions.

Individual Behavior Management: Individual behavior management is equally important in optimizing air conditioning usage. Residents should cultivate habits of using air conditioning responsibly, such as setting the temperature within the recommended range of 26-28°C, avoiding excessively low settings, and minimizing unnecessary energy waste. Regular maintenance, such as cleaning the AC unit, will help maintain optimal functioning and improve its energy efficiency. Additionally, residents should adjust AC usage based on weather changes and indoor comfort, avoiding prolonged continuous operation.

In summary, optimizing air conditioning usage behavior requires not only improving the living environment and enhancing policy guidance but also promoting social cultural changes and individual behavior management. These efforts will contribute to achieving energy conservation and emission reduction goals, while advancing environmental sustainability. The integrated implementation of these strategies will lay a solid foundation for more efficient and environmentally friendly air conditioning usage.

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