[*RESEARCH ON OCCUPANTS ENERGY-SAVING RELATED RETROFITTING BEHAVIOR BASED ON MOA MODEL——TAKING TIANJIN AS AN EXAMPLE*]

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Abstract

The improvement of indoor comfort of existing residential buildings is one of the important aspects of urban stock planning. Active utilization of appropriate energy-saving measures in the renovation tasks will bring social, economic and environmental benefits to the city. Under such circumstances, this paper takes the residents as the research object, and collects the data through a combination of on-the-spot interview and online questionnaire. Based on the MOA (Motivation-Opportunity-Ability) framework, this paper explores the main factors affecting the retrofits from the three aspects of Motivation, Opportunity and Ability, and constructed the conceptual model of "Energy-saving related Retrofits in Residential Buildings under the MOA framework". The results show that: Motivation directly affects the retrofitting behavior, and there is a positive interaction among Opportunity, Ability and Motivation. On the Motivation level, "safety" and "thermal comfort" are the strongest, followed by "energy saving" "space function" "maintenance of damaged sections" and "appreciation"; the main influencing factors on the Opportunity level are "material acquisition" "personal time" "construction workers" "retrofit-based technologies" and "new concepts and products"; on the Ability level, "funds" plays the most important role, followed by "family support" and "professional experience". From the perspective of occupants, this paper makes an empirical analysis of the factors that affect the energy-saving retrofits of residential buildings, thus providing reference for building a livable living environment.

Keywords: Existing Residential Buildings; Energy-saving related; Retrofits; Factor Analysis; "Motivation—Opportunity—Ability" Model; Tianjin

0. Overview

Residential communities in China have entered the period of stock-based planning. Increasing the energy efficiency of the residential buildings to enhance the residential comfort as well as reduce their high share of the energy consumption could have various societal benefits. Taking Tianjin as an example, in the central urban area, there are 2,192 communities which were built prior to 2000 (MHURD, 2015), and currently they cannot meet the normal use of residents. The renovation of external environment of existing residential areas led by the government has been constantly promoted. However, the energy-efficiency related retrofitting of residential interior is commonly low. In order to get a clear picture of this problem, the analysis is conducted on the factors influencing the energy-related refurbishment projects in Tianjin.

With regard to the retrofitting of existing residential buildings, foreign scholars have made diverse attempts. In addition to energy-saving measures and the related predictions on energy-saving efficiency, a series of studies are conducted from the perspective of occupants. For example, the research on the influential factors of residential retrofitting by Germany owners is carried out (M Achtnicht, 2014), and on the basis of this, an empirical research is launched (B Robert, 2017), which shows that the intention of house embellishment, the need for building maintenance, and the quest for the related know-how facilitate the energy-related refurbishment projects. Besides, from an economic perspective, the studies such as the willingness to pay for the energy-saving measures in residential buildings(S Banfi, 2008), the occupants' decision-making and behaviour analysis through the approach of behavioral economics(E R Frederiks, 2015), and the intentions to upgrade the energy standards of private houses in Norway from the viewpoint of psychology(C A Klöckner, 2014), have laid theoretical foundation for the research on the energy-efficient retrofitting of existing residential buildings.

Chinese scholars have delivered fruitful outcomes in terms of energy-saving retrofitting measures, energy-consumption assessment and implementation mechanism of residential buildings. The research from the perspective of occupants has also been focused. Based on the survey of selected communities in Tianjin (Liu Yadong, 2010), the research on the residents' requirement for retrofitting has been conducted, and the analysis on the main influential factors of residential satisfaction and their significance is launched. An empirical study on the residential behaviour of Beijing residents has put forward a structural equation model to construct the residential satisfaction model with the aid of exploratory factor analysis (ZHAN Dongsheng, 2014); the research on the factors influencing the residents' willingness for house upgrade is carried out, and the target population is classified into 3 groups to propose the methods for building up a low-carbon city(Wang Zhuoran, 2017).

These studies provide insights for the occupants' efforts in terms of energy-efficient residential retrofitting, and also demonstrate the important role of residents' subjective initiative. Therefore, this article, proceeding from the occupants' behaviour in energy-saving related retrofitting, by means of empirical case studies, illustrates the main factors affecting the current process of residential retrofitting in Tianjin, in order to facilitate the energy-saving renovation of residential buildings.

1.Methods

2 .1 "Motivation - Opportunity - Ability" Framework

The model of Motivation - Opportunity - Ability, called MOA, provides a well-structured analytical framework for the driving forces of individual information behavior from the following three aspects: the subjective possibility of behavior, the objective possibility of behavior, and the possible effect of subjective behavior on objective cognition(Chen Zeqian, 2013). The MOA model, originating from the basic concepts of psychology, can be adopted to explain and analyze the driving forces related to human behaviour (K F Hew, 2007). Since the MOA-related theories are open and adaptable, researchers should get a detailed picture of the model's specific meanings and roles, according to the theoretical basis of related disciplines and the particular situations, and set up a mechanism of reasonable actions and measures.

In the studies on the energy-saving related retrofits of residential buildings in Tianjin, "Motivation" refers to whether the residents' desire of house renovation can be satisfied or not. "Opportunity" refers to such factors as basic environment, technologies, social conditions, etc which exert positive or negative influence on house renovation. "Ability" refers to the factors of residents' experience, knowledge and funds related to house renovation. House retrofits are driven by these MOA factors, which play their roles respectively (L Argote, 2003) This paper, based on the MOA model, proceeds from the research achievements registered by some scholars, and, in conjunction with a series of interviews and investigations conducted in Tianjin, extracts the specific evaluation factors of Motivation, Opportunity and Ability.

Guide for Energy-saving Retrofit of Existing Residential Buildings (MHURD, 2012) defines the "energy-saving related retrofits": the maintenance of insulation and heating systems, heat sources and pipe networks, and the comprehensive energy-saving renovation. Therefore, this paper, based on the research related to the existing residential buildings (Liu Ming,2017; Wang Lijun, 2011; Tian Yiwei, 2013) combined with the Tianjin-specific situations, sums up the major aspects of the behaviour of house retrofits in Tianjin (Table 1), of which Behavior 2 - 9 serve as the measures of house retrofits. In addition, based on the previous studies on strategies of house renovation(LIU Xiaojun, 2015; He Shenjing, 2014;), residential satisfaction (Liu Zhilin, 2015; Li Zhigang, 2011) and so on, this paper identifies the specific factors of Motivation (Table 1), Opportunity (Table 2) and Ability (Table 3), so as to get a complete picture of house retrofits influenced by the MOA factors.

Table 1 Behavior of House Retrofits

Behavior	Description
1 Beautify the environment	Paint walls, replace floors, and so on
2 Renovate doors and windows	Replace, repair and fix doors and windows
3 Repair damaged sections	Repair the sections on the ground, walls and other structures which have been damaged
4 Make use of solar energy	Utilize solar-energy equipment
5 Renovate heating equipment	Replace and upgrade heating equipment
6 Utilize water-saving equipment	Replace old-fashioned water equipment with water-saving taps, showers, toilets, and so on
7 Utilize electricity-saving equipment	Replace old-fashioned electricity equipment with electricity-saving lamps, electrical appliances, and so on
8 Renovate ventilation systems	Add and renovate ventilation equipment
9 Others	Other house retrofits

Table 2 Factor of House Retrofits: Motivation

Motivation	Description
M1 Environment upgrade	Makes the indoor space more tidy, beautiful and pleasant
M2 Maintenance of damaged sections	Repair the sections on the ground, walls and other structures which have been damaged
M3 Thermal comfort	Enhance the insulation performance and improve ventilation:
M4 Space function	Optimize indoor functions to make the space more convenient and user-friendly
M5 Energy saving	Make the building more water-saving and electricity-saving
M6 Retrofits for the elderly	Provide senior citizens with a more convenient, safe and comfortable living environment
M7 Safety	Make the building and its structures safer, keep lives and properties in safe
M8 Appreciation	Create more economic values for the building

Table 3 Factor of House Retrofits: Opportunity

Opportunity	Description
O1 Policy encouragement	Related policies to call for house retrofits
O2 Community support	Community support for house retrofits
O3 Retrofit-based technologies	Sophisticated retrofit-based technologies, easy for construction tasks
O4 Construction workers	Easy to find a quality construction team
O5 Material acquisition	Easy to purchase satisfactory construction materials
O6 Period of house retrofits	A short period of house retrofits, no need to move out of the building
O7 Neighborhood impact	Little negative impact on neighborhood
O8 Existing restrictions	Not restricted by the existing facilities of the building
O9 New concepts and products	New concepts of household decoration / Wide application of new products → More ease for house retrofits
O10 Personal time	Enough time for house retrofits

Table 4 Factor of House Retrofits: Ability

Ability	Description
A1 Funds	Enough funds for house retrofits
A2 Professional experience	Knowledge and experience related to house retrofits, not difficult
A3 Family support	Family support for house retrofits

According to the above-mentioned influencing factors, the questionnaire falls into three parts: collection of basic information, behavior of house retrofits, and investigation of influencing factors. Likert Scale is adopted in the investigation of influencing factors, with 5 levels: 1 - the lowest; 5 - the highest (1: far from consistent, 2: not consistent, 3: general, 4: more consistent, 5: totally consistent).

2 .2 Structural Equation Modelling (SEM)

This paper, based on the MOA framework, proposes a MOA model of energy-saving related house retrofits (Figure 1), including the structural model (the hypothesis about the relationship between Motivation, Opportunity, Ability and the retrofitting behavior) and the measurement model of various latent variables. In the initial model, Motivation directly affects the behavior of house retrofits, while Opportunity and Ability affect the retrofitting behavior indirectly through the influence of Motivation; besides, Opportunity and Ability interact with each other. Therefore, this paper proposes the following hypothesis: H1 - Motivation directly affects the behavior of house retrofits; H2 - Opportunity is positively related to Motivation; H3 - Ability is positively related to Motivation; H4 - Opportunity is positively related to Ability.

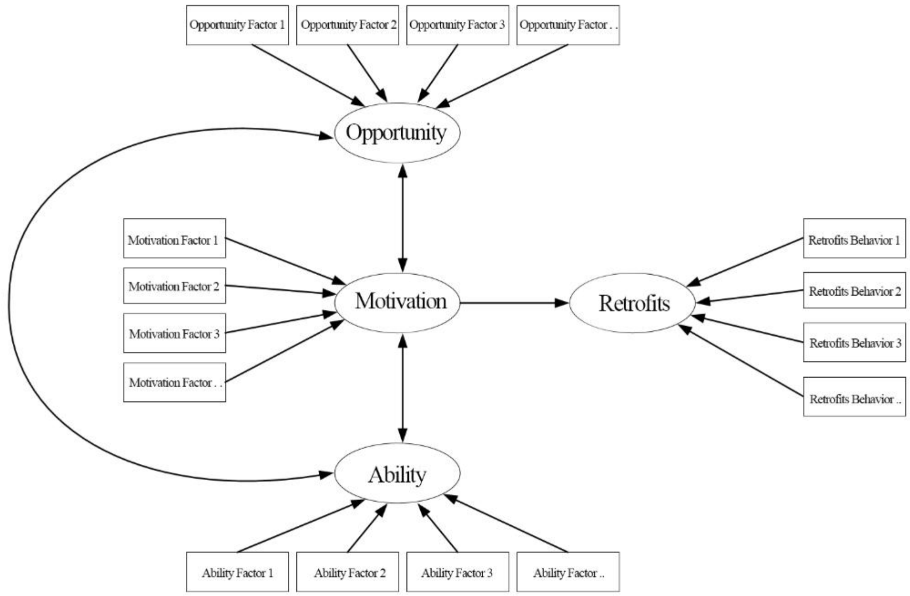


Figure 1 The MOA Initial Model of Energy-saving Related House Retrofits

3 Data Analysis

3.1 Data sources

With Tianjin residents as the research object, we apply field research, in-depth interviews, and questionnaire surveys to investigate the projects of energy-saving retrofitting launched by residents. By means of online survey, the general factors influencing the adoption of energy-related refurbishment projects by the approach of the Motivation-Opportunity-Ability framework are carried out.

A total of 927 online questionnaires have been collected from December 2017 to March 2018. Those samples filled with irrational answers in an extremely short period of time have been eliminated, and emphasis is laid on the samples in which the measures related to the energy-saving retrofitting are expounded. Thus, finally, 814 valid questionnaires which account for 87.8% of the total questionnaires have been identified (Table 5) .The effects on the refurbishment extent of occupants in the process of such projects are analyzed with structural equation analysis.

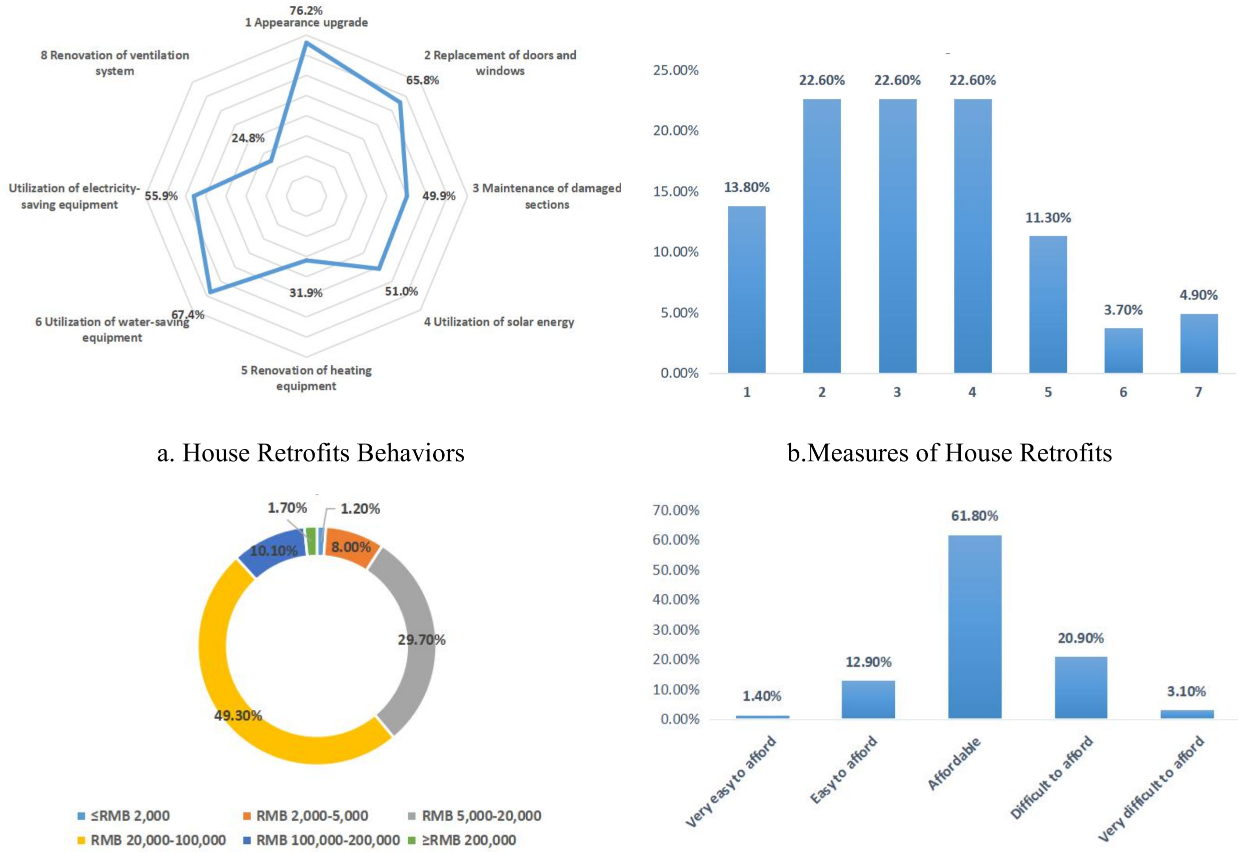
Table 5 Basic information of Valid Samples

Items surveyed	Description	Percentage	Items surveyed	Description	Percentage
Ownership	Owners	90.2%	Building area	≤30 ㎡	1.2%
	Tenants	9.8%		31-60 ㎡	6.1%
Age	18-25 years old	8.8%		61-80 ㎡	15.0%
	26-30 years old	31.1%		81-100 ㎡	27.3%
	31-40 years old	44.9%		101-120 ㎡	29.1%
	41-50 years old	10.9%		121-150 ㎡	13.0%
	51-60 years old	4.5%		151-200 ㎡	4.1%
	Above 60 years old	1.2%		201-300 ㎡	4.2%

3.2 Analysis on Retrofitting Behavior

According to the questionnaire, the behaviour of most residents falls into 8 categories (Figure 2), as is shown in the Table 1. In addition, a small number of residents (1.8%) carry out such renovation tasks as installing intelligent household systems, replacing old furniture, upgrading water, electricity and pipe networks, and so on. Among the retrofitting behavior, appearance upgrade ranks at the top: 73.2%; utilization of water-saving equipment: 66.4%; replacement of doors and windows: 65.8%; utilization of electricity-saving equipment: 55.9%; maintenance of structures: 49.9%. It can be seen from the questionnaire that those tasks of house retrofits accounting for 50%+ is fairly easy to perform and have a small impact on the existing buildings. In terms of energy-saving measures, most of the residents adopt 2 or 4 measures, accounting for 22.6% respectively.

In terms of renovation cost, nearly half of the residents (49.3%) have spent RMB 20,000-100,000. In terms of consumer affordability, 61.8% of the residents can afford the expense of house retrofits. From the cross statistics of renovation cost and consumer affordability (Table 8), it can be seen that 254 residents (31.2%) have spent RMB 20,000-100,000, a moderate level of their consumer affordability; 99 residents (20.0%) have spent RMB 2,000-10,000, a moderate level of their consumer affordability. This shows that about half of the residents are willing to spend a considerable sum of money on their house retrofits. RMB 20,000-100,000 is the most common price range, followed by RMB 2,000-10,000.



a. House Retrofits Behaviors

b.Measures of House Retrofits

c. Renovation cost

d.Consumer affordability

Figure 2 House Retrofits Information

3.3 Model of Retrofitting Behavior

In this paper, the SPSS software is adopted for data analysis. The reliability of the questionnaire is tested by means of Cronbach's Alpha and Composite Reliability. If all the results are greater than the recommended parameter of 0.7, the questionnaire is reliable. Prior to the analysis on various factors, KMO and Bartlett Spherical Tests are performed on 21 variables which affect residential satisfaction. The KMO value is 0.903, and the significance value of Bartlett Spherical Test is 0.000. The results show that the data, with a sound correlation, is suitable for factor analysis.

In the analysis on factor validation, after those factors with low loads are edited out, AVEs (Average Variance Extracted) of Motivation and Ability reach 0.5, while AVE of Opportunity (0.495) is lower than the average. With regard to Motivation, 2 factors with low loads are edited out: "environment upgrade" (0.594) and "retrofits for the elderly" (0.509). With regard to Opportunity, 4 factors with low loads are edited out: "policy encouragement" (0.480), "community support" (0.528), "period of house retrofits" (0.558), and "neighborhood impact" (0.563). The results of factor validation (Table 6) show that all the remaining factors are reliable and valid.

Table 6 Results of factor validation

Latent variables	Observed variables	Normalized factor load	Cronbach's Alpha	Composite Reliability	AVE
Motivation	M2 Maintenance of damaged sections	0.652	0.783	0.858	0.503
	M3 Thermal comfort	0.771			
	M4 Space function	0.657			
	M5 Energy saving	0.714			
	M7 Safety	0.799			
	M8 Appreciation	0.646			
Opportunity	O3 Retrofit-based technologies	0.646	0.850	0.842	0.495
	O4 Construction workers	0.692			
	O5 Material acquisition	0.722			
	O8 Existing restrictions	0.725			
	O9 New concepts and products	0.681			
	O10 Personal time	0.713			
Ability	A1 Funds	0.761	0.732	0.750	0.502
	A2 Professional experience	0.673			
	A3 Family support	0.687			

In this paper, AMOS (Structural Equation Modelling) is adopted to conduct the path analysis on the model, and the fitting indexes of the initial model are identified. By analyzing the indexes and combining the related theories, the fitting of the model is further improved, after the residual among "retrofit-based technologies" "construction workers" and "the material acquisition" is associated. All the indexes of the revised model are up to the recommended values(Wu Longming, 2016), and thus the model has a good fitting.

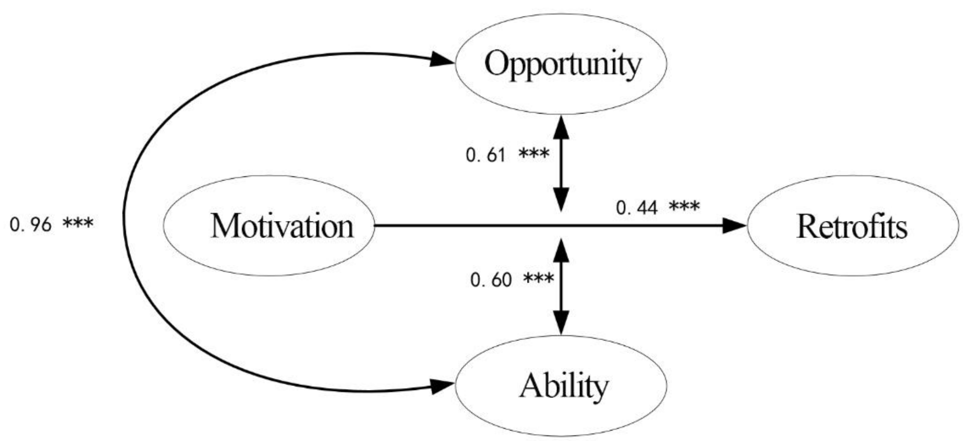


Figure 3 The Revised Model

From the revised structural equation modelling, it can be seen that Motivation directly affects the behavior of house retrofits, which is consistent with the Hypothesis 1; there is also a clear positive correlation among Opportunity, Ability and Motivation, which is consistent with Hypothesis 2 to Hypothesis 4. The correlation between Opportunity and Ability is strongest, and the coefficient of standardized path among Opportunity (0.61), Ability (0.60) and Motivation is almost equal, which indicates that they exert similar influence on house retrofits.

Table 7 Analysis on Coefficient of SEM Path

Latent variables	Observed variables	Coefficient of standardized path	P value
Motivation	M2 Maintenance of damaged sections	0.652	***
	M3 Thermal comfort	0.771	***
	M4 Space function	0.657	***
	M5 Energy saving	0.713	***
	M7 Safety	0.799	***
	M 8 Appreciation	0.644	***
Opportunity	O3 Retrofit-based technologies	0.711	***
	O4 Construction workers	0.708	***

	O5 Material acquisition	0.726	***
	O8 Existing restrictions	0.679	***
	O9 New concepts and products	0.691	***
	O10 Personal time	0.713	***
Ability	A1 Funds	0.760	***
	A2 Professional experience	0.671	***
	A3 Family support	0.690	***

According to the analytical results, with regard to Motivation, "safety" is the most significant influencing factor, followed by "thermal comfort" "energy saving" "space function" "maintenance of damaged sections", and "appreciation". This indicates that safety, thermal comfort, etc are the main requirements of house retrofits, and the willingness in this respect is strongest. Besides, "energy saving" is also a major influencing factor. Such influencing factors as "retrofits for the elderly" and "environment upgrade" are edited out due to insufficient influence. "Retrofits for the elderly" has the weakest influence, which indicates that the retrofits serving the needs of senior citizens fail to promote the energy-saving related retrofits of residential buildings.

With regard to Opportunity, such influencing factors as "material acquisition" "personal time" "retrofit-based technologies" and "construction workers" exert strong influence, followed by "existing restrictions" and "retrofit-based technologies", which indicates that sufficient construction materials and workers, as well as sophisticated technologies, serve as a boon for house retrofits. In addition, the influencing factors of "policy encouragement" and "community support" play an unobvious role. However, this does not mean that they have little effect on the energy-saving related retrofits of residential buildings. Instead, the surveyed retrofitting behaviour suffers the lack of policy encouragement and community support.

With regard to Ability, "funds" is the most important influencing factor. Ample funds will greatly promote the energy-saving related house retrofits. Besides, the influencing factor of "family support" plays a slightly stronger role than its counterpart - "professional experience".

4. Results

In this article, which targets at Tianjin residents, efforts are made to set up the conceptual model of "Motivation—Opportunity—Ability for Behavior of Residential Retrofitting", and their relationship is illustrated by means of questionnaire survey and the fitting of structural equation model.

Our results show that the intention of house embellishment, the need for building maintenance, and the quest for the related know-how facilitate more comprehensive energy-related refurbishment projects. The research shows that the motivation of residential retrofitting exerts direct influence upon the energy-related refurbishment behaviour and the positive interaction is obvious among opportunity, ability and motivation. As for the motivation, the need of safety and enhancement of interior thermal comfort serves as the catalyst of residential retrofitting, followed by the quest for energy-saving performance, the improvement for functional layout, the need for building maintenance, as well as the demand of value enhancement; as for the opportunity, such influential factors as the acquisition of materials, personal time, retrofitting-based technologies, construction personnel, and so on are identified; as for the ability, refurbishment expense plays the most important role, followed by family support and professional expertise. The analysis on the influential factors of energy-saving residential retrofitting is conducted, based on the needs of occupants, which provides reference for creating an energy-efficient and liveable environment.

5. Discussion

We can see, based on the model analysis, that residential retrofitting is mainly driven by such factors as daily safety and interior thermal comfort, which indicates that currently in terms of residential buildings, there are many daunting challenges to be addressed in the possible shortest period. Apart from this, as for the opportunity, policy support plays an insignificant role, and a wide gap is obvious between policy support and other factors, meaning that in the previous practice of independently-launched energy-saving residential retrofitting, more efforts should be made for a higher standard of policy support. In conjunction with other factors, the conclusion can be drawn that the behaviour of energy-saving residential retrofitting will be promoted to a large degree, if the policies and strategies with regard to the acquisition of materials, personal time, retrofitting-based technologies, construction personnel, and so on are materialized.

In this article, with the Tianjin citizens' behaviour of energy-saving residential retrofitting as the research object, the in-depth analysis is conducted on the driving forces of house upgrade from the perspective of occupants, as well as the main factors influencing the independently-launched energy-saving residential retrofitting. Based on these efforts, we can get a clear picture of those difficulties encountered by residents, and with the aid of scheme optimization, technical support, policy guidance, and so on, create supportive conditions for them to participate in the projects of house upgrade, so as to ensure that the related projects proceed in an unimpeded manner, enhance the residential satisfaction of occupants, and facilitate a virtuous cycle of residential retrofitting.

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