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SEM-Based Research on Influence Factors of Energy Conservation in Operation and Maintenance of Construction Project

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ABSTRACT
The energy consumption in operation and maintenance stage of construction project accounts for 80% of the whole project life cycle and therefore research on influence factors of energy consumption in project operation and maintenance stage is of great practical significance. Based on data of 260 valid questionnaires in Jiangsu area, structural equation model is adopted in the Thesis for empirical research on influence factors in operation and maintenance stage. Based on theoretical analysis and factor analysis, the conceptual model and research hypothesis for influence factors of energy consumption in operation and maintenance stage are proposed to establish structural equation model and to carry out empirical test on conceptual model as well as research and construction. The research results show that: (1) the government policy has obvious positive effects on selection and adoption of energy-saving technology as well as energy conservation will of project participates (2) cognition of the public has obvious effects on energy conservation will, energy-saving technology has obvious effects on facility management and facility management has obvious effects on users' cognition (3) the direct influences of government policy on energy-saving technology and users' cognition have not reached the significance level specified in statistics and the direct influences of facility management and energy-saving technology on energy conservation will have also not reached the significance level specified in statistics.

KEY WORDS: Conceptual model, Facility management, Empirical analysis, Operation and maintenance, Research on energy conservation, Structural equation model

1 INTRODUCTION

AT present, researches on influence factors of building energy conservation mainly focus on design and construction stage and there are rare researches on operation and maintenance stage of buildings. The cost of buildings in construction stage only accounts for 25% of total cost in its life cycle and the cost in service stage accounts for 75%. Therefore, it is necessary to carry out in-depth research on influence factors of energy consumption in operation and maintenance stage (Sha 2003; Li et al., 2018). Relevant foreign researches mainly focus on current situation and influence factors of facility management (Sun 2007). C Eglnond analyzes from the perspective of policy subsidies to study the extent to which energy-saving subsidies have made additional investments in the public to achieve energy-saving goals (C Eglnond et al., 2010). David conducted a survey of some users in Australia and found that the public's awareness of energy conservation and energy-saving behaviour are positively correlated (Gadenne et al., 2011). Hwang conducted an investigation and comparison of safety performance and critical safety issues between green and conventional building construction projects in Singapore (Hwang et al., 2011). Ma presents a novel method for contextualizing and enriching large semantic knowledge bases for opinion mining with a focus on Web intelligence platforms (Ma et al., 2017). Palm and Steg investigated the public's income level, influenced by factors such as the educational process, and combined the energy conservation awareness and social responsibility norms to study the impact on energy

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saving willingness(Palm 2010; Steg 2008).Up to now, there are no literatures of empirical research on influence factors of relevant government policy, developers' benefits, energy-saving technology, public cognition, facility management and other factors on operation and maintenance stage of buildings(Tsang et al., 2017). For this purpose, an empirical research will be carried out in the Thesis for this problem so as to enrich and develop existing theoretical achievements.

2 MATERIAL AND METHODS

THE thesis mainly focuses on four aspects such as government, developers, users and facility management and energy conservation awareness and energy-saving technology are regarded as internal reason representation of influences of energy consumption in operation and maintenance and government policy is regarded as representation of external reasons of society(Ignacio et al., 2009). At the same time, facility management companies and energy conservation will are taken into consideration to explore relationship between these factors(Aigbavboa et al., 2009).

2.1 Model dimension design

(1) Government policy. Government's policy guidance will influence the balance between developers' enterprise performance and energy-saving technology, energy conservation awareness of the public, facility management companies and other aspects(Wang et al., 2017). In the Thesis, government policy is defined as publicity and education of national and local governments related to energy conservation, energy conservation subsidy for enterprises and the public, medium or short-term planning and suggestions etc.

(2) Energy-saving technology. As the specific development organization, developers pay much attention to the fact that input cost of energy-saving technology in previous stage will occupy enterprises' benefit space and whether energy conservation cost will have reasonable return through policy support or transferring and other ways. The energy-saving technology defined in the Thesis refers to new-type energy-saving materials, energy-saving construction method and green construction technology etc. used by developers in construction process.

(3) Energy conservation awareness. Energy conservation awareness refers to the public's initiative and consciousness of changing and adopting substitutable resources to realize energy conservation and environment protection through their behaviors in shortage of energy (Mao et al., 2017). The energy conservation awareness defined in the Thesis refers to energy utilization habits and recognition degree of energy conservation of owners or users of buildings.

(4) Facility management. To a great extent, the energy consumption in operation and maintenance stage depends on equipment operation management and maintenance level which are directly influenced by level of facility management companies. In our country, main implementation departments of facility management are property management companies. Therefore, the facility management defined in the Thesis refers to the direct cooperation between property management companies responsible for operation management and equipment maintenance with owners and users after the construction project is delivered.

(5) Energy conservation will. Will is the measurement of possibility for individuals to take characteristic actions. In general, in case individuals' will of some behaviour is stronger, the possibility of taking the behaviour will be higher. In the Thesis, acceptance of will is defined to be will of developers, users and facility management companies to take energy conservation behaviours so as to measure possibility of all project participates to take energy conservation behaviours in operation and maintenance stage.

2.2 Research hypothesis

Based on analysis of influence factors of building energy conservation and literature review of operation and maintenance management (Long et al. 2010; Lu 2010; Sun 2010; Fu and Liu, 2017), it is hypothesized in this research: government policy has influences on energy-saving technology, energy conservation awareness, facility management and will acceptance, energy-saving technology has influences on facility management and will acceptance, facility management has influences on energy conservation awareness and cognition as well as will acceptance and the energy conservation awareness has direct influences on will acceptance. The conceptual model is shown in Figure 1.

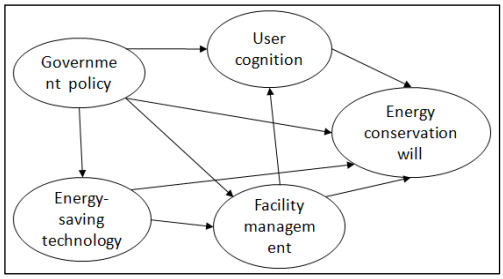

Figure 1. Conceptual model.

(1) Research hypothesis for dimensionality of government policy.

In energy conservation and emission reduction as well as promotion of new technology, government is always the leading force for promotion of energy-saving technology and users' cognition and facility management is influenced by government policy to a certain degree. The following hypotheses are proposed in the Thesis:

H1a: government policy may have obvious influences on developers' adoption of energy-saving technology.

H1b: government policy may have obvious influences on cognition of owners and users.

H1c: government policy may have obvious influences on facility management.

H1d: government policy may have obvious influences on energy conservation will.

(2) Research hypothesis for dimensionality of energy-saving technology.

From perspective of technological development, green building and energy-saving technology are directions of construction development in the future. The following hypotheses are proposed in the Thesis:

H2a: energy-saving technology may have obvious influences on energy conservation will.

H2b: energy-saving technology may have obvious influences on facility management.

(3) Research hypothesis for dimensionality of facility management.

In dimensionality of facility management, the following hypotheses are proposed in the Thesis:

H3a: facility management may have obvious influences on users' cognition.

H3b: facility management may have obvious influences on energy conservation will.

(4) Research hypothesis for dimensionality of users' cognition.

In dimensionality of users' cognition, the following hypotheses are proposed in the Thesis:

H4a: users' cognition may have obvious influences on energy conservation will.

3 RESULTS

TO ensure scientificity and validity of research, the form of structural questionnaire is adopted to acquire relevant data by referring to existing research achievements based on dimensionality analysis of above-mentioned models. Lickert 5-class scaling method is adopted to measure variables in questionnaire and 1 point refers to lowest influence degree and 5 points refer to the highest influence degree(Alex et al., 2017). The design of questionnaire includes two stages: the first is based on previous theoretical researches to preliminarily determine indicator system of influence factors of energy conservation in operation and maintenance stage; the second is to make determined main indicators into initial questionnaire and enterprises and experts in this industry are selected for investigation. And then initial questionnaire is modified according to opinion feedback and suggestions of experts so as to finally determine a formal questionnaire scale.

3.1 Research samples

The research group will distribute questionnaires in various construction companies, residence community, office building, supermarkets and other places in Xuzhou City according to random principle. Besides, distribution of different industry groups covering traditional energy, building, service, public institutions, colleges and universities is taken into consideration. The questionnaire is filled in three forms such as e-mail, field visit and test in Circle of Friends. 350 questionnaires are distributed and 284 questionnaires are recovered and the recovery rate is 81.14%. In all recovered questionnaires, there are 260 valid questionnaires and the proportion of valid questionnaire is 91.55%.

Exploratory factor analysis and empirical factor analysis will be adopted for measured data so as to test reliability and validity of scale (Wolsink 2007; Mi et al., 2015). Reliability Analysis with SPSS19.0 is adopted to calculate Cronbaca's Alpha coefficient of questionnaire data and the result is 0.854 and the combined reliability of total scale is 0.5, which shows the questionnaire is relatively reasonable and conforms to reliability requirements. By KMO sampling adequacy test and Bartlett test, we will know KMO test coefficient is 0.795, statistical magnitude of Bartlett is 2296.572 and the significance probability is 0.000 (0.05 less than significance level), which shows measured data are basically suitable for factor analysis (Dietz et al. 1999; Jia et al., 2017).

Principal component analysis is adopted to carry out exploratory factor analysis. According to scree test principle of scree plot and points of observed indicators, the orthogonal rotation with maximum variance is adopted to eliminate 2 items with load less than 0.5; there are 5 common factors in all and the load of each common factor is above 0.55 and the Cronbaca's Alpha value of each factor is above 0.8 and contribution rate of accumulative variance is 73.793%. The common information consisting of each factor item makes up the implicit feature of the factor, which shows data in scale have favorable differentiation and convergence validity. (Refer to Table 1).

3.2 Data verification

5 common factors will be selected from 21 observation indicators in questionnaire: 5 manifest variables contained in factor 1 (ZC) reflect influences of government policy on energy conservation will and then common factor 1 is named "government policy"; 5 manifest variables contained in factor 2 reflects influences of developers' selection and application of energy-saving technology on energy conservation will and the common factor 2 is named "energy-saving technology"; 4 manifest variables contained in factor 3 reflect users' cognition and understanding of energy-saving hospital and the common factor 3 is named "users' cognition"; 5 manifest variables contained in factor 4 reflect influences of facility management on energy conservation will and the common factor 4 is named "facility management"; 2 manifest variables

Table 1. Factor load matrix

Observed variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Government formulates economic incentive policy (ZC1)	0.855				
Provide subsidy for utilization of new energy-saving technology (ZC2)	0.853				
Supervision on enterprises and individuals (ZC3)	0.845				
Propaganda of energy conservation ideas (ZC4)	0.805				
Regulate and control market and enhance competitive advantage of energy conservation (ZC5)	0.671				
Initial investment and profit margin of developers (JS1)		0.920			
Cost and expected returns of energy conservation (JS2)		0.901			
Risks in selection and application of energy-saving technology (JS3)		0.892			
To select and apply green construction technology or not (JS4)		0.758			
Sustainable development management of energy-saving technology (JS5)		0.662			
To select and apply low-carbon consumption pattern nor not (RZ1)			0.865		
Recognition degree of energy conservation promotion (RZ2)			0.853		
Practicability reflection of energy conservation (RZ3)			0.849		
To frequently acquire energy conservation information or not (RZ4)			0.841		
Overall level of property management (SS1)				0.881	
Operation and maintenance level of equipment (SS2)				0.851	
Level of facility management talents (SS3)				0.800	
Energy conservation ideas in facility management (SS4)				0.754	
Favorable long-term energy conservation effects after basic investment (YY1)					0.830
Favorable energy conservation effects acquired from cooperation of interested parties of the project (YY2)					0.758

Note. ZC refers to government policy, JS is energy-saving technology, RZ is users' cognition, SS is facility management and YY is energy conservation will

contained in common factor 5 reflect subjective energy conservation will of the subject and then common factor 5 is named "energy conservation will".

Amos 21.0 software will be used in the Thesis to carry out empirical analysis for 5 factors acquired from exploratory factor analysis and the path coefficient and some fit indexes will be used to measure fitting degree of factor structure and observed variables so as to verify reasonability and feasibility of the whole model (Chan 2001). Results are shown in Fig. 2. It can be seen from Figure 2 that the correlation coefficient between five factors acquired from exploratory analysis is less than 0.50 and does not reach significance level. Therefore, there is no high-order common factor between these five factors. It can be seen from estimation of first-order model that corresponding fit indexes of the model reach inspection standard; after the scale structure constituting the model is modified, reliability and validity are relatively ideal; in overall collocation degree of first-order model, after its goodness of fit index (GFI) and normative fit index (NFI) and other indexes reach fitting standard, the convergence effects of the model are better; fall factors constituting the model have favourable discriminatory validity and the factor load is more than 0.5.

4 DISCUSSION

Cronbach's α is used to test consistency of structure inside latent variable; coefficient of composite reliability index (C.R) and extracted average variance (AVE) are used as measurement index of reliability and all values of test index in scale are shown in Table

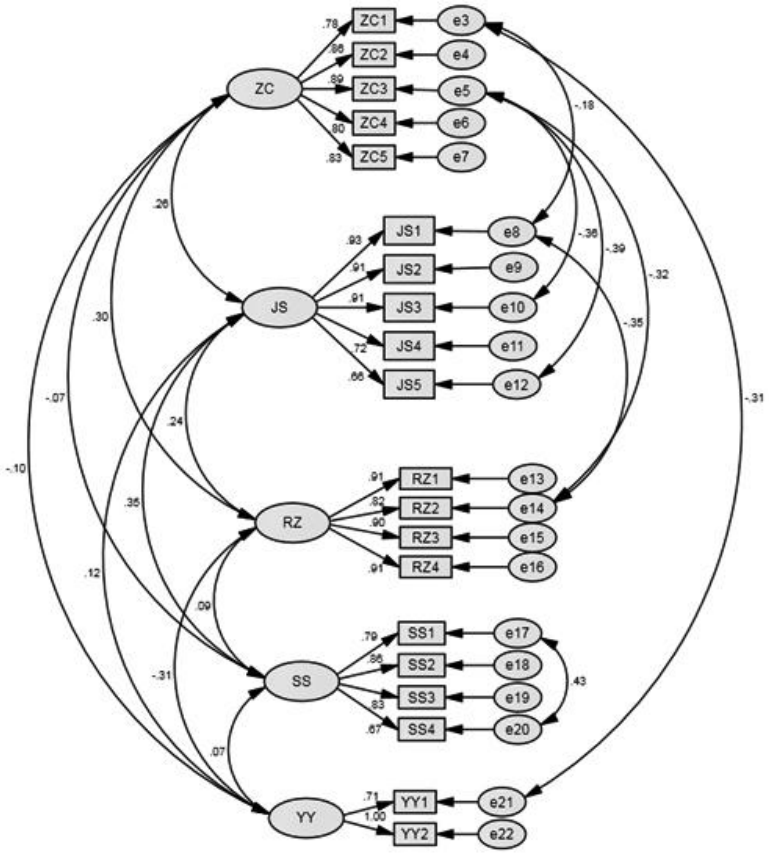

Figure 2. Estimation of parameters in first-order model

Note. ZC: government policy; ZC1: economy incentive policy formulated by the government; ZC2: subsidy for application of new energy-saving technology; ZC3: supervision of enterprises and individuals; ZC4: propaganda of energy conservation ideas; ZC5: regulate and control market and enhance competitive advantages of energy conservation; JS: energy-saving technology; JS1: initial investment of profit margin of developers; JS2: cost and expected return of energy conservation; JS3: risks in selection and application of energy-saving technology; JS4: to select and apply green construction technology or not; JS5: sustainable development management of energy-saving technology; RZ: users' cognition; RZ1: to select and apply low-carbon consumption pattern nor not; RZ2: recognition degree of energy conservation promotion; RZ3: practicability reflection of energy conservation; RZ4: to frequently acquire energy conservation information or not; SS: facility management; SS1: overall level of property management; SS2: operation and maintenance level of equipment; SS3: level of facility management talents; SS4: energy conservation ideas in facility management; YY: energy conservation will; YY1: favorable long-term energy conservation effects after basic investment; YY2: favorable energy conservation effects acquired from cooperation of interested parties of the project.

2. In general, the Cronbach's α of all measurement indexes of the same latent variable shall be greater than 0.7, the factor load is greater than 0.5 and CR and AVE are respectively greater than the minimum critical value 0.7 and 0.5, which shows inherent quality of model is favourable (Rong 2008). The result shows that Cronbach's α of all latent variables reach requirements and factor load of all manifest variables reach the standard of being greater than 0.5, which shows the affiliation between latent variables and manifest variables is apparent.

Validity test includes two measurement indexes such as convergence validity and structure validity and extracted average variance (AVE) is adopted in the Thesis to test convergence validity and structure validity of the scale. In general, when the value of AVE is greater than 0.5, it shows the convergence validity of scale is favorable; when arithmetic square root of AVE of all latent variables is greater than the correlation coefficient of the latent variable with other latent variables, the scale has relatively higher structure validity(Liu et al. 2011). It can be known from analysis results in Table 2 that C.R value of 5 latent variables is greater than standard threshold value-0.7 and AVE is greater than 0.5, which shows the measurement model has favorable convergence validity and structure validity.

AMOS18.0 software is used to carry out fitting degree analysis on initial hypothesis model and data sample and fitting indexes of various indexes are

Table 2. Reliability and validity test of measurement model

Latent variable	Observed variable	Factor load	α coefficient	Composite reliability C.R	AVE
Government policy	Government formulates economic incentive policy (ZC1)	0.895	0.902	0.9088	0.6671
	Provide subsidy for utilization of new energy-saving technology (ZC2)	0.865			
	Supervision on enterprises and individuals (ZC3)	0.794			
	Propaganda of energy conservation ideas (ZC4)	0.793			
	Regulate and control market and enhance competitive advantage of energy conservation (ZC5)	0.726			
Users' cognition	To select and apply low-carbon consumption pattern nor not (RZ1)	0.914	0.934	0.9351	0.7832
	Recognition degree of energy conservation promotion (RZ2)	0.910			
	Practicability reflection of energy conservation (RZ3)	0.899			
	To frequently acquire energy conservation information or not (RZ4)	0.813			
Energy-saving technology	Initial investment and profit margin of developers (JS1)	0.927	0.914	0.9174	0.6933
	Cost and expected returns of energy conservation (JS2)	0.907			
	Risks in selection and application of energy-saving technology (JS3)	0.910			
	To select and apply green construction technology or not (JS4)	0.717			
	Sustainable development management of energy-saving technology (JS5)	0.665			
Facility management	Overall level of property management (SS1)	0.859	0.879	0.8814	0.6507
	Operation and maintenance level of equipment (SS2)	0.821			
	Level of facility management talents (SS3)	0.760			
	Energy conservation ideas in facility management (SS4)	0.783			
Energy conservation will	Favorable long-term energy conservation effects after basic investment (YY1)	0.876	0.833	0.8342	0.7158
	Favorable energy conservation effects acquired from cooperation of interested parties of the project (YY2)	0.815			

Note. standard for Cronbach's α is no less than 0.6, standard for C.R (composite reliability) is no less than 0.7 and standard for AVE (extracted square difference) is no less than 0.5.

shown in Table 3. Bentler says (Bentler 1990), as for the model containing multiple variable models, it is very difficult to completely reach generally recognized goodness of fit. Even though GFI and AGFI do not reach standard of 0.9, values of IFI, NFI and CFI are greater than 0.9, the proportion between chi-square and freedom degree is 1 to 3 and AIC conforms to requirements. Therefore, it is allowed to carry out hypothesis test. (Refer to Table 3)

Maximum likelihood estimation (ML) is adopted in the Thesis to test the hypothesis model and test results are shown in Table 4.

Table 3. Fitting index of model

Index name		Fit index	Evaluation of fitting
Absolute fit index	GFI	0.891	Acceptable
	RMR	0.043	Yes
	AGFI	0.878	Acceptable
	IFI	0.956	Yes
Relative fit index	NFI	0.924	Yes
	TLI	0.947	Yes
	CFI	0.956	Yes
Information index	AIC	360.702	Yes
	CAIC	553.692	Yes

5 CONCLUSIONS

THE research is based on SEM and the model of influence factor of energy conservation in operation and maintenance stage of construction project is established to carry out empirical analysis on energy conservation will in operation and maintenance stage from four aspects such as government, project construction party, facility management party and public factors. From analysis, we can draw the following conclusions: (1) Energy conservation will also have positive effects. In case government provides more support for energy-saving technology,

Table 4. Analysis of model hypothesis and test

Hypothesis	Influence path	S.E.	Standard path coefficient	P	To accept original hypothesis or not
H1a	Energy-saving technology<-- government policy	0.108	0.729	***	Accepted
H1b	Users' cognition <--- government policy	0.011	0.074	0.503	Rejected
H1c	Facility management <--- government policy	0.051	-0.051	0.737	Rejected
H1d	Energy conservation will <--- government policy	0.107	0.628	0.035	Accepted
H2a	Energy conservation will <---users' cognition	0.282	0.325	***	Accepted
H2b	Facility management <---energy-saving technology	0.147	0.630	***	Accepted
H3a	Users' cognition <---facility management	0.190	0.662	***	Accepted
H3b	Energy conservation will<---facility management	0.070	0.072	0.299	Rejected
H4a	Energy conservation will<--- energy-saving technology	0.043	-0.076	0.297	Rejected

Note. *** expresses P is less than 0.001

corresponding supervision policy is more impeccable and the orientation of green building is more obvious, the construction party's energy conservation awareness and low-carbon selection tendency will be stronger and influences of all project participants' energy conservation will are more obvious.

(2) To ensure energy conservation, new techniques, technologies and materials adopted by project construction party have positive effects on subsequent energy-saving management of facility management companies; at the same time, in operation and maintenance stage of the project, facility management companies directly influence users' cognition, which means facility management mode with relatively stronger energy conservation awareness can facilitate users' energy conservation habits and behaviors.

(3) Influences of government policy on users' cognition and facility management do not reach the significance level specified in statistics and influences of facility management and energy-saving technology on energy conservation will also do not reach the significance level specified in statistics. However, government policy has obvious influences on energy-saving technology, energy-saving technology has obvious influences on facility management and facility management has direct and positive influences on users' cognition. Therefore, government policy indirectly influences facility management and users' cognition. This is also the disproof that government shall enhance publicity of energy conservation and environment protection and issue privilege and reward policy for energy conservation so as to facilitate developers in using energy-saving technology and have positive influences on energy conservation will of project participants.

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