Analysis on the Influencing Factors of BIM Technology Application in Engineering Cost Management

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Abstract: The degree of adoption of BIM technology varies for each different stage of engineering cost management. We construct multiple ordered Logistic regression model through questionnaire survey. The results show that the adoption degree of BIM technology in engineering cost management is good. In the bidding stage, BIM technology is used to a high degree in engineering quantity calculation, bidding list, contract price and model correlation, project estimation, etc. In the delivery and operation stage, BIM technology is adopted to a high degree in order to optimize project operation. To provides practical guidance for the application of BIM technology in the whole process of cost management, this paper puts forward three suggestions for the application of BIM technology in project cost management.

Keywords: engineering cost management; BIM technology adoption; logistic regression model

1 Introduction

At present, the use of BIM technology in the United States, Singapore, the four Nordic countries and other countries has been quite advanced. BIM technology in China has not yet entered a mature period. It is in the development period. But it still brings irreplaceable technical contributions to China's engineering practice. In the construction process, good engineering cost management is a very necessary and critical part of the whole process. The application of BIM technology in construction project cost management can accurately estimate the project cost and assist construction enterprises to do a good job both in the decision-making and design of engineering projects and the whole process of bidding construction. This paper analyzes the key factors influencing the adoption of BIM technology in engineering cost management, which promotes China's construction industry to a higher stage of information technology. We try to provide practical guidance for the whole process of cost management of BIM technology.

Engineering cost management reasonably uses scientific technology and methods to conduct the whole process and organizational activities of all business in line with policies and objective laws. Now the research in engineering cost is more theoretical. [1, 4, 6, 8].

The practical application of BIM technology in cost management has been widely recognized by all levels of society. BIM technology is relatively less used throughout the cost management process: [5, 7, 9].

EMIS 2023, February 24-26, Chengdu, People's Republic of China

DOI 10.4108/eai.24-2-2023.2330689

With the development of economic and technological societies, The link between the Internet and construction cost management is getting closer. However, there is still a slight gap between the research results of how to combine the three organically and the research results related to the project cost. At the same time, many scholars have conducted a lot of research on BIM technology and engineering cost management. The actual work will always face huge cost data. But manual accounting often leads to errors. The current management model cannot solve the problem of efficiency. Existing studies have shown that using BIM technology applied to engineering cost management is a way to solve the above problems. Therefore, this paper analyzes the influencing factors of the application of BIM technology in project cost management. It also provides practical guidance and specific suggestions for the application of BIM technology in the whole process of cost management.

2 STUDY DESIGN

2.1 The Idea of Questionnaire Design

The purpose of this research evaluation system is to investigate the factors affecting the adoption of BIM technology in various project stages, and to reflect the current situation of relevant engineering personnel using BIM technology in cost management. The survey is conducted in the form of a questionnaire, following the principles of systematic scientificity, purpose and logic. The questionnaire is scientifically adapted on the basis of a 5-point Likert scale. And it is used to measure the variables and the relationship between variables involved in the model in the empirical research stage. The questionnaire consists of the basic information of the respondents and the decomposition of engineering projects regarding costing. We selecte from engineering-related workers in cities ranging from one to five tier cities across the country as the research subjects to ensure the integrity and authenticity of the data. In order to ensure the universality of age, gender and other aspects of the universality index as far as possible, this study selected the departments related to the cost of the selected unit and carried out random sampling of workers.

2.2 Questionnaire Option Setting and Scoring Method

This paper mainly analyzes the basic personal information, project cost, interviewees' basic information, project process and other aspects. Each indicator is further subdivided into several indicators to study the influencing factors of BIM technology adoption in engineering cost management. The specific classification of factors affecting BIM technology adoption is shown in Table 1. The specific dependent and independent variables are set and assigned as shown in the following table:

Table 1: The assignment table of various factor.

FACTOR COMPONENT	FACTOR	VARIABLES	ASSIGNMENT DESCRIPTION
BASIC INFORMATION OF THE RESPONDENTS	Age	X1	1=20-30 years old, 2=31-40 years old, 3=41-50 years old, 4=51 years old and above
	Gender	X2	1= male, 2= female
	Work in the city	X3	1 = first-tier city, 2 = second-tier city,

			3 = third-tier city, 4 = fourth-tier city, 5 = fifth-tier city
	Education level	X4	1=doctor and above,2=master,3=bachelor,4=bachelor and below
	Qualification of the unit	X5	1=special grade qualification,2=first grade qualification,3=second grade qualification,4=third grade qualification,5=other
	Time spent working in engineering-related work	X6	1=0-5 years, 2=6-10 years, 3=11-20 years, 4=20-30 years, 5=31 years and above
	Engaged in engineering work positions	X7	1=cost engineer, 2=structural engineer, 3=supervisory engineer, 4=equipment engineer, 5=construction manager
PROJECT PROCESS DECOMPOSITION	Cost control in the decision-making stage	X8	1=Program selection, 2=Investment analysis, 3=Project economic evaluation, 4=Financing analysis
	Cost control in the design stage	X9	1=Model creation, 2=Collision check, 3=Design estimate budgeting
	Cost control in the bidding stage	X10	1=volume calculation, 2=bidding list, 3=contract price associated with model, 4=project estimate, 5=budget review
	Cost control in the construction stage	X11	1=Construction simulation, 2=Progress control, 3=Materials and dynamic cost control, 4=Measurement and payment, 5=Change control
	Cost control in the delivery and operation stage	X12	1=Completion and finalization, 2=Optimization of project operation, 3=Equipment maintenance and repair costs
DEPENDENT VARIABLE	BIM technology adoption level	Y	1= no adoption at all, 2= relatively low adoption, 3= good adoption, 4= relatively large adoption, 5= high adoption

The first type of factors is "personal basic information", including age, gender, working city, education level, unit qualification, project-related working time, and engineering job position. Therefore, options X1 to X7 are set in the questionnaire. The age and time of the relevant job can reflect different categories of people. For example, fresh graduates, middle-aged people with rich work experience and experienced employees have different views on BIM technology in project cost. The city of work reflects the adoption of BIM technology in construction costing by people in different workplaces. Education level and workplace qualification reflect the adoption of BIM technology in construction costing. According to the educational background and qualification of the unit, the adoption of BIM technology by talents with different educational background and working environment level is discussed. Managers can better understand the influencing factors of BIM technology adoption by workers in different engineering stages.

The second category of factors is "decomposition of engineering projects in terms of cost", including cost control in decision stage, cost control in design stage, cost control in bidding stage, cost control in construction stage and cost control in delivery operation stage[9]. The investment decision stage is the pre-stage of project cost management. Only correct investment decision can calculate reasonable and meaningful project cost, including program selection, investment analysis, project economic evaluation, and financing analysis. The cost control in the design stage is often carried out by the design unit according to its proposed construction plan or construction drawings, including model creation, collision check, design estimate budget. The cost control in the bidding stage requires the bidding parties to calculate the price of the project according to their own perspectives and positions, including quantity calculation, bidding list, contract price and model correlation, project estimate and budget audit. The construction stage is the center of the whole life cycle of the construction unit and the contractor.   The management of the project cost mainly includes construction simulation, schedule control, materials and construction cost. Delivery and operation stage refers to the process in which both parties settle all completed construction products and pay the project price according to the specific provisions of the construction contract, including completion settlement, final accounting, project operation optimization, equipment maintenance and repair costs, etc (Kong Linhua 2017). Therefore, the options X8 to X12 are set in the questionnaire.

2.3 Model Building

Logistic Regression model is a probability model, which is a regression model based on the probability P of an event as the dependent variable and the factors affecting P as the independent variable, analyzing the relationship between the probability of an event and the independent variable [3]. This questionnaire is based on the Logistic regression model, establishing the BIM technology adopted in the process of project cost as a research model. We use the empirical model to analyze the influencing factors affecting the adoption of BIM technology in the whole process of cost. Multiple Logistic regression model is applicable to the case of multinomial dependent variables, which can be divided into disorder and order. When studying the influencing factors of BIM technology adoption in engineering cost management, multiple classification is more convincing than two classification. At the same time, based on the adoption degree of this paper, the adoption is divided into five levels. Therefore, multiple Logistic regression model is adopted in this paper. Its model is as follows:

$$Y = Log(\frac{p}{1-p}) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + \mathbf{KK} + b_nX_n \tag{1}$$

Where b_0 is the constant term, b_1 to b_n are the regression coefficients of the logistic model, which are the estimated parameters of the logistic model regression, and X_1 to X_n are the independent variables. The left-hand side of the model is the natural logarithmic value of the probability of the event occurring.

3 EMPIRICAL ANALYSIS

3.1 Questionnaire Distribution and Recovery

The questionnaires were distributed in the form of a professional questionnaire distribution platform, disseminated through the Internet. The respondents came from six different types of engineering project enterprises. A total of 301 questionnaires were distributed (including 151 men and 150 women, the proportion of men and women is basically the same;). A total of 271 questionnaires were collected. Among them, 70 invalid questionnaires with incomplete or normal answers were excluded, and 201 were confirmed to be valid. The investigation efficiency was 66.8%. The urban coverage is concentrated in the first - and second-tier cities, accounting for 62.69%. The interview age was concentrated in 20 -40 years old, accounting for 64.68%. The education level of the interviewed population is concentrated in the majority of undergraduate and master's degree, accounting for 71.64%.

3.2 Questionnaire Reliability and Validity Test

Cronbach's alpha or Cronbach's α is a statistical quantity, which is the average of the discounted reliability coefficients obtained from all possible item classification methods of the scale. It also is the most commonly used reliability measure. Reliability analysis, i.e., reliability analysis, was conducted using Cronbach's alpha or Cronbach's α. Reliability coefficients greater than 0.8 indicate very credible: 0.7 to 0.8 indicate very high reliability, 0.6 to 0.7 indicate very credible, 0.5 to 0.6 indicate credible, and less than 0.5 indicate not credible. The test result of this study was 0.724, indicating very high credibility of the survey data.

The KMO test statistic is an indicator for comparing the simple and partial correlation coefficients between variables, which takes values between 0 and 1. Bartlett's sphericity test is a method used to test the degree of correlation between variables and is used to determine whether the variables are suitable for factor analysis. Validity analysis is a measure of the validity of the data. The questionnaire was analyzed for structural validity using KMO values and Bartlett's sphericity test values, with KMO values greater than 0.9 indicating a good fit, 0.7 to 0.9 indicating a good fit, 0.6 indicating a poor fit, and less than 0.5 being unsuitable for factor analysis. The KMO value of this study is 0.730, which indicates good validity of the questionnaire. The significance level of Bartlett's sphericity test for each part and the overall is less than 0.01, indicating that the reliability test is suitable and can be analyzed in the next step.

3.3 Analysis of Multiple Logistic Regression Results

Table2: Results of the ordered multivariate Logistic model estimation.

		Estimate	se	Wald	df	Sig.	OR	OR 95% CI	
								Lower	Upper
threshold	[Y = 1]	-6.300	0.769	67.073	1.000	0.000	0.002	0.000	0.008
	[Y = 2]	-5.444	0.741	53.947	1.000	0.000	0.004	0.001	0.018
	[Y = 3]	-3.583	0.716	25.048	1.000	0.000	0.028	0.007	0.113
position	[X9=1]	-1.013	0.390	6.741	1.000	**0.009**	0.363	0.169	0.780

[X9=2]	-1.073	0.384	7.833	1.000	**0.005**	0.342	0.161	0.725
[X10=1]	0.904	0.426	4.508	1.000	**0.034**	2.469	1.073	5.692
[X10=2]	0.865	0.403	4.602	1.000	**0.032**	2.375	1.078	5.233
[X10=3]	1.619	0.434	13.897	1.000	**0.000**	5.048	2.155	11.811
[X10=4]	1.483	0.449	10.892	1.000	**0.001**	4.406	1.826	10.633
[X11=1]	-0.962	0.465	4.277	1.000	**0.039**	0.382	0.154	0.951
[X11=3]	-1.008	0.435	5.359	1.000	**0.021**	0.365	0.155	0.856
[X12=2]	1.014	0.320	10.023	1.000	**0.002**	2.757	1.471	5.165

As shown in Table 2, which is the estimation result of ordered multivariate logistic model, the adoption level of BIM technology in engineering cost management is good. BIM technology has high adoption level in model creation and inspection, material and cost control, and operation control, etc. And the focus on developing BIM technology in these aspects may become a major focus.

Among them, X1 age, X2 gender, X4 education level and X8 cost control at the decision stage have no effect on the adoption of BIM technology ($p > 0.05$). The correlation coefficient of x1 to x7 indicators is negative, indicating that the BIM technology is not widely used. Probably because the Adoption of BIM technology is influenced by personal subjective factors. Different knowledge of BIM technology and personal different awareness of BIM technology and different habits will affect people's adoption of BIM technology. In the cost control of X9 design stage, the adoption of BIM technology is lower for collision checking ($p = 0.009$) and model creation ($p = 0.005$). It may be because collision detection is a technical difficulty in the application of BIM. And in the design process using CAD and other previous basic software for model creation more people. In the cost control of X10 bidding stage, the quantity calculation, bidding list, contract price and model association and project estimate have high adoption of BIM technology. Using BIM for bidding is a new type of engineering contracting transaction means in construction market. In recent years, for bidders, BIM can truly provide the engineering entity information needed in quantity calculation to quickly and accurately calculate the quantity of work. X11 in cost control of construction stage, construction model ($p = 0.039$) and material and dynamic cost control ($p = 0.021$) have low adoption of BIM technology. The construction schedule preparation completed by applying BIM technology is generally more accurate. The amount of resources needed for each construction process and construction node is accurately calculated, but its actual application is still relatively small. X12 in the cost control of delivery and operation stage, optimizing project operation has high adoption of BIM ($p = 0.00$). In the cost control of X12 delivery operation stage, the optimization project operation has a high degree of BIM adoption ($p = 0.002$). The use of building models containing complete project information can be used in the optimization project process. For example, for equipment management, the electronic model should contain all the information of the equipment, which can be directly located to use its brand, performance, installation and other information.

4 CONCLUSIONS AND RECOMMENDATIONS

In this paper, with the help of survey data and adopting multivariate ordered logistic regression model, the influencing factors of BIM technology adoption in engineering cost management are divided into 12 indicators. It is concluded that the degree of adoption of BIM technology in engineering cost management is important. In the bidding stage, the application of BIM technology has higher requirements for engineering quantity calculation, bidding list, correlation between contract price and model and engineering estimation. In the delivery operation stage, the adoption of BIM technology is higher for optimizing project operation. In the design and construction stage of cost control, the adoption of BIM technology is lower. To provide practical guidance for BIM technology for the whole process of cost management, the following suggestions are made.

(1) Adopt BIM technology more on the basis of the basic software such as CAD in the past. In the design phase, attempts were made to break through the difficulty of collision detection and refine the creation of the model. The 3D model display allows reviewers, owners and users to see the design effects at a glance. In the construction phase, it is more convenient to use BIM technology to complete the compilation and control of construction progress.

(2) In the stage of the high degree of BIM technology, it is necessary to refine its research and application. In the bidding stage, BIM technology is used to analyze and compare the model data, and the construction simulation is used to compare the scheme to further improve the efficiency of bidding. In the delivery and operation stage, BIM technology can be used to collect complete and structured building information. After the completion of settlement, we can quickly count the completed project tasks, refine and optimize the project operation.

(3) Design organizations need to popularize the advantages of BIM technology to practitioners and further develop the digital functions under the BIM platform. BIM model, as the core for each participant to comprehensively grasp the global information of the building, enables practitioners to integrate resources more effectively and systematically and consider improving their own working methods, and comprehensively collect the project cost data through the digital platform for timely and structured processing of the project.

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