IOP Conference Series: Earth and Environmental Science

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To cite this article: Yanyan Ke *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **632** 022053

View the article online for updates and enhancements.

Study on the Maturity of Construction Technology in China

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Abstract. The development and application of construction have two sides, advanced technology may lead to efficiency improvement and performance improvement, but may also because of the lack of technology itself, resulting in economic losses, security risks, ecological damage and other negative effects. Based on the CMM model, the paper takes construction technology as the research object, constructs the construction technology maturity evaluation system, and takes the data of the National Bureau of Statistics from 1999 to 2018 for nearly 20 years as the analysis sample to evaluate the construction technology maturity grade. On this basis, the paper puts forward some suggestions to improve the maturity of construction technology.

Keywords: Construction industry, Construction technology, Maturity model, Maturity analysis.

1. Introduction

The development of construction technology has changed the mode of production of society and improved people's quality of life, but with the progress of technology, there are many problems and negative effects such as the construction cost by the application of new technology is rising instead of falling, and it's difficult to spread because of the complexity and limitation of specialty, as well as the energy loss, environmental pollution and global warming caused by urbanization and other problems and negative effects that needed to be solved. We must scientifically understand the two sides of the development and application of technology: on the one hand, it's possible to improve economic efficiency and performance, on the other hand, it may also due to the lack of maturity of the technology itself, resulting in economic losses, security risks and ecological damage and other negative effects. Therefore, it is of great significance for the development of construction technology and construction industry to construct technology maturity model based on current national conditions and to analyze and evaluate the maturity level of construction technology in China.

Construction technology is a broad concept, covering a wide range of modules, including architectural design, building structure, building construction, decoration, water supply and drainage, HVAC refrigeration, engineering cost and other modules. Although the coverage of construction technology has different classification and partition forms for different research objects, the kernel of construction technology is unified. Based on the characteristics of "development degree, coordination degree and sustainability degree" of sustainable development, the maturity index of building

IOP Conf. Series: Earth and Environmental Science **632** (2021) 022053 doi:10.1088/1755-1315/632/2/022053

technology is decided into four sub-indicators: quality, economy, environmental protection and technological potential, and then discusses the construction technology level of construction industry.

2. Research methods

There are more than 30 kinds of technology maturity models in academic field, among which CMM model, OPM3 model and K-PMMM model are the most common. CMM model (Capability Maturity Model for Software) was proposed by software engineering institute (SEI) of Carnegie-Melon University in 2001, this model is widely used in the field of software development to evaluate software development capabilities and help them improve software quality. At the same time, it is also the foundation of project management maturity model. OPM3 model based on the CMM model, the American Association for Project Management (PMI) proposed the project management maturity model (PMI-OPM3) in 2003. The K-PMMM model was proposed by Dr. Cozner, a prominent consultant in the United States in 2001, K-PMMM model focus on the strategic perspective of enterprise project management to identify the current problems of project management. The paper studies and analyzes the characteristics and evolution of construction technology based on a thorough study of the relevant literature on construction technology and technology maturity. Comparing with several typical maturity models and combining with the characteristics of construction technology, the paper thinks that the CMM model and construction technology have a large degree of compatibility, so we choose to make appropriate adjustments on the basis of CMM model to establish construction technology maturity model. Based on the above discussion and analysis, the maturity model of construction technology is finally established. Taking the construction technology as the research object, the maturity level is divided into five steps, which are in turn progressive spiral upward: initial level, potential level, improvement level, integration level and optimization level.

3. Results and Analysis

3.1. Evaluation indexes of construction technology maturity rating in construction industry

The evaluation indexes of construction technology maturity are determined by the key domains (KPA) and key practices (KP) constructed above. But because both of them are abstract and subjective, in order to make the evaluation results objective and credible, the evaluation indexes are re-selected. Although KPA and KP are the basis for the selection of evaluation indicators, they are not completely one-to-one correspondence.

Based on the previous analysis, the paper summarizes the relevant theoretical knowledge of the technology maturity model. The first-level evaluation index of maturity model is composed of three ~ five evaluation indexes in abstract or general, and the second-level index expands three ~ five concrete or concrete evaluation indexes on the basis of each first-level index.

3.2. Construction of Evaluation System

For the purpose of ensuring the authenticity and authority of the data, this study sets the time span for nearly 20 years from 1999 to 2018, and uses the annual data recorded on the official website of the National Statistics Bureau of the People’s Republic of China (National Data) as the object of data analysis.

Table 1. Evaluation Index of Construction Technology Maturity.

Initial indicators	First indicators	Second indicators	Corresponding data	
			Number of enterprises for quality supervision and inspection of building materials products	A1
		Product pass rate	Proportion of enterprises with unqualified products in quality supervision and inspection of building materials products	A2
	Quality (A)	Technical equipment rate Annual completion rate	Quality supervision and inspection batch qualified rate of building materials products	A3
			Technical equipment rate of construction enterprises	A4
			Completion rate of building area in construction enterprises	A5
		Total industrial output	Total construction output	B1
Evaluation Index of Construction Technology Maturity	Economic (B)	Industry value added	Labour productivity of construction enterprises in terms of total construction output	B2
		Labour productivity	Construction industry added value	B3
			Total construction investment	B4
			Urban greening area	C1
	Environmental Protection (C)	Greening rate Energy consumption Waste recovery input value	Investment in construction and installation of fixed assets in waste resources and waste materials recycling and processing industry	C2
			Total energy consumption in construction	C3
		Patent admissibility rate	Number of building accepted	D1
			Number of building patent applications	D2
	Research Potential (D)	Patent authorization Academic attention	Number of papers on civil construction science and technology included in SCI	D3

For data processing, IBM SPSS 22.0 data analysis software is selected for principal component analysis, so as to simplify the calculation steps, avoid calculation errors, and finally get the analysis results. The basic idea of principal component analysis is to project a given related original variable into a new space with the help of linear transformation, so as to calculate a set of new feature groups linearly related to the original feature in decreasing order of importance from big to small from the original set of features. In the whole transformation process, the total variance of variables remains unchanged, among which the first variable with the largest variance is the first principal component, and the second variable with the second largest variance is the second principal component, and so on, n variables have n principal components, and each principal component is not related.

Suppose that the study of a problem involves p indicators, expressed as X_1, X_2,..., X_P, and the P indicators make up P-dimensional random variable, expressed as $X=(X_1, X_2,..., X_P)$. Then the i principal component of X can be expressed as $Y_I=u_I'X$, i=1, 2,..., P.

U_I is column ith vector of the orthogonal matrix and meet the follow conditions:

(1) Yi is the largest variance in the linear combination of $X_1, X_2,..., X_P$; Y_K, which is independent to linear combination of $Y_1,…, Y_{K-1}$, is the largest variance in the linear combination of $X_1, X_2,..., X_P$, k=2, 3,..., p.

(2) $u_{i1}^2+ u_{i2}^2+...+u_{ip}^2=1$ (i=1, 2,…, p)

(3) $Yi=u_{i1}X_1+u_{i2}X_2+...+u_{ip}X_p$

3.3. Calculation results

3.3.1. Calculation process. Firstly, the SPSS software is used to standardize the data, then the descriptive statistics are carried out for the variables, and then the principal component analysis and total variation are carried out to obtain the component scoring coefficient.

Table 2. Descriptive Statistics and Component Score Rating Coefficient Table.

		Descriptive statistics					Component score coefficient matrix		
		N	123	123	123		1	2	3
Quality indicators	A1	20	19850	89859	61403.85	17803.336	.196	.226	.977
	A2	20	10	18	13.94	1.754	.402	.206	-.314
	A3	20	82.6	93	86.655	2.1970	-.421	-.154	.252
	A4	20	5756	13458	9884.20	2035.133	-.180	.487	-.289
	A5	20	31.8	51.9	41.275	6.9293	.219	-.476	-.051
Economic indicators	B1	20	11152.9	235086	94289.384	75893.7719	.318	-.167	
	B2	20	53328	368243	197113.10	111571.288	.317	-.136	
	B3	20	5180.9	61808	25768.605	18853.1886	.318	-.143	
	B4	20	198530466.7	9845322567	1767306577.852	2283938164.1756177	.136	1.040	
Environmental indicators	C1	16	2178.53	7696.41	4495.3925	1883.90556	.344	-.090	-6.681
	C2	14	132.12	292.13	211.7041	53.70073	.337	2.366	3.208
	C3	15	2.68	1066.45	338.4860	363.04539	.337	-2.270	3.609
Technological potential indicators	D1	19	1600	61100	17836.79	18784.459	.340	-1.437	
	D2	19	1373	34485	10651.89	10964.728	.339	-1.624	
	D3	12	351	2460	936.58	663.088	.334	3.111	

3.3.2. Principle component analysis results. Based on the data obtained above in the original scoring coefficient matrix divided by the standard deviation square corresponding to the principle component in the descriptive statistical data table, and total weight coefficient (expressed in Ci) corresponding to each indicators in each principal component for construction maturity index can be obtained, thus the calculating formula of the maturity index can be obtained:

$$F1 = 0.786 * C11 + 0.172 * C12 + 0.233 * C13$$

$$F2 = 0.813 * C21 + 0.114 * C22$$

$$F3 = 0.734 * C31 + 0.103 * C32 + 0.128 * C33$$

$$F4 = 0.734 * C41 + 0.372 * C42$$

$$Index\_M = \sum_{i=1}^{n} F_i * v_i$$

By software calculation, we can get the trend curve of technology maturity index change.

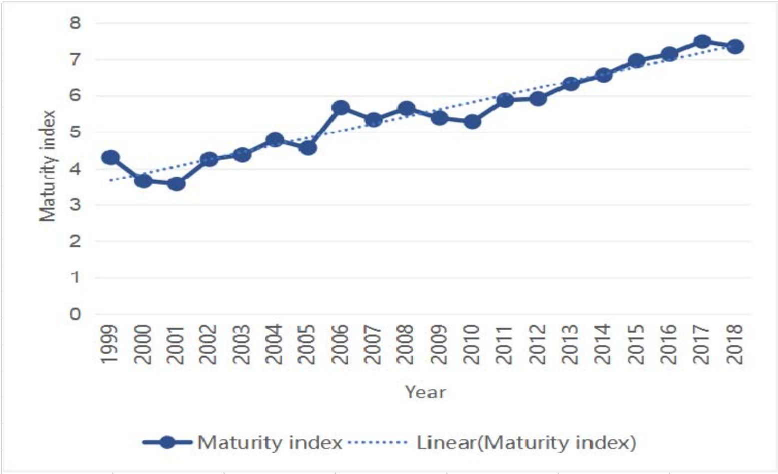

Figure 1. Change trend in construction technology maturity index.

It can be seen from the above chart that from 1999 to 2018, the comprehensive index of maturity of China's construction technology maturity index is relatively flat, showing an overall upward trend, and is in the process of gradual transformation from the improvement level to the integration level. The development trend is stable and the development prospect is broad, but there is also a large room for improvement.

4. Recommendations

4.1. Pathways and recommendations for quality
In terms of quality, the proportion of enterprises with unqualified products has been controlled below 20% in recent years, and there is a slight downward trend. Considering that the overall qualified rate of building materials is more than 82% due to technical constraints and objective factors, it can be seen that there is a certain guarantee. In order to improve the construction technology maturity level, the government should establish a more perfect standard system related to standardization and quantitative, strengthen the supervision of market enterprises, so as to reduce the proportion of non-conforming products in marketing.

4.2. Pathways and recommendations for economy
In terms of economy, the total investment, total output value, added value, remuneration of construction workers and labor productivity of construction enterprises all show a continuous upward trend with the increase of the year. To raise the level of construction technology maturity, the state needs to continue to pay attention to and invest in the construction industry, and construction enterprises should also adopt advanced scientific and humanized management methods to improve the labor productivity of construction enterprises, so as to ensure the steady increase pf labor output value of construction industry. On the other hand, the state should introduce relevant policies to appropriately increase the remuneration of workers in the construction industry.

4.3. Pathways and recommendations for environment
The energy consumption of the construction industry is increasing year by year, although it is the embodiment of rapid increase of the total output value of the construction industry, but it has also consumed a lot of energy, and also increased the emissions of carbon dioxide and harmful gases, leading to environmental pollution and global warming. In order to raise the level of construction technology maturity, the government should continue to pay more attention to and invest in environmental protection, and increase investment in urban greening projects and waste recycling. On

the other hand, we should also pay attention to investment in scientific research, improve the utilization rate of energy through the improvement of construction technology.

4.4. Pathways and recommendations for scientific and technological potential
In terms of scientific and technological potential, the number of building patent applications is increasing year by year, especially taking the year 2000 as a the boundary, the growth rate has changed from the original flat growth to the rapid growth, reflecting the construction enterprises pay more and more attention to patent technology. On the other hand, the number of papers on civil engineering and science and technology included in SCI has also increased rapidly in recent years, reflecting the increasing attention of the academic community to the construction industry and related research. The state should improve the patent awareness of the general public, timely introduce and implement relevant policies and regulations to protect patents. At the same time, the state should continue to step up efforts to support relevant scientific research projects, and vigorously promote the application and popularization of advanced technology.

5. Conclusion
The paper summarizes the relevant theoretical knowledge of common technology maturity models, combines the characteristics of the construction industry, and constructs the construction technology maturity model based on the CMM model. The model is divided into five steps, each step is progressive and optimized, and the key domain (KPA) and key practice (KP) of the maturity model are obtained in combination with the current situation of industry development. According to the characteristics of construction technology in the construction industry, four abstract primary indicators corresponding to the maturity model are formulated: quality, economy, environmental protection, scientific research potential, and the secondary indicators are further obtained according to the primary indicators, and the relevant national data (National Date) are found according to the secondary indicators, through the data analysis software for integration analysis, and finally get the construction technology maturity of the construction industry. Through the analysis of the construction technology maturity of the construction industry, it is obtained that from 1999 to 2018, the maturity of the construction technology in China has reached a steady development and gradual rise, which has realized the gradual transformation from the improvement level to the integration level, and has continued to move towards to the optimization level and strive to develop.

Acknowledgments
This work was financially supported by Educational research project for young and mid-aged teacher in Fujian Province. (Project Number: FBJG20180114)

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