Research on the Construct and Dimensions of Low-Carbon Production Behavior of Public Projects

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ABSTRACT. *The construction of public projects plays a key role in the realization of economic and social sustainable development and urban prosperity. China has made remarkable achievements in public projects, such as the Hong Kong-Zhuhai-Macau Bridge, the Three Gorges Project, the Bird's Nest Project, and the Shanghai World Expo Axis Project. In order to stimulate further economic growth, China needs more public projects. However, in the process of public project construction and management, waste of resources and environmental damage are serious. It is crucial to improve the low-carbon production behavior and low-carbon performance of public projects. Based on the previous literature research results, combining with the characteristics and interview results of public projects, this paper constructs a three-dimensional framework of low-carbon production behavior of public projects including 15 key factors. The key factors identified in this paper, on the one hand, can be used as the basis of the follow-up research, on the other hand, can provide a reference for the low-carbon production behavior management of public projects.*

KEYWORDS: *public project, low-carbon production behaviors, structural dimension, attribute characteristic.*

1. Introduction

China's public projects have achieved many miracles. The public projects represented by the Hong Kong-Zhuhai-Macao Bridge, the fully automated wharf of Shanghai Yangshan Port, the New Beijing Airport, the Beijing-Xinjiang Expressway, and the Qinling Tunnels are becoming the new cards of Chinese creation. Public projects refer to a type of engineering construction projects that have great and far-reaching impacts on the national economy and social development. The amount of investment, the consumption of social and natural resources, the time of existence, and the impact on the ecological environment of large-scale public projects are much higher than those of ordinary projects. The harmonious coexistence of large-scale public projects with the social environment and natural environment can not only promote the sustainable development of the project but also further promote the ecological balance of the project, society, and environment. The relationship between economic growth and carbon emissions is inverted-U shaped [1]. In recent years, the government has been increasing investment in public projects, which has effectively driven economic growth, but exposed a series of problems such as unsatisfactory investment performance, waste of resources, environmental pollution, and neglect of low-carbon emission reduction [2]. Therefore, the study of low-carbon production behavior of public projects is of great significance to solve the performance dilemma, solve the inefficient crisis, improve the management ability of public projects and make it conform to the development of a low-carbon economy.

2. Ecosystem functions of large-scale public projects

The ecosystem has the structure and function of self-adaptation and self-organization [3]. The ecosystem exists not only in the natural biological system and social system but also in large-scale public projects, as shown in the Figure 1. From a macro perspective, the ecosystem of large-scale public projects refers to a relatively stable and constrained ecosystem formed by the interaction between the ecological population of large-scale public projects and its community environment, social environment, and natural environment. It is a combination of artificial system and natural system.

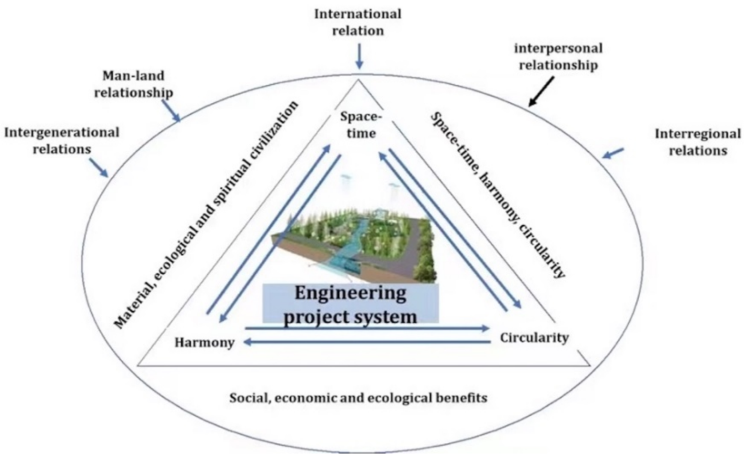

Figure. 1 The relationship between public engineering ecosystem and ecosystem

The ecosystem function of large-scale public projects includes basic function and dynamic function. And the basic functions include service function and restore

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function. 1) Service function: Service function is the most essential function of large-scale public projects. The purpose of the construction of large-scale public projects is to meet the needs of the upper system and the society. 2) Restore function: The proposal of the restoration function of large-scale public projects is based on the basic contradiction between the unlimited expansion of human demand capacity and the limited bearing capacity of the natural environment. The restoration function requires that the construction of large-scale public projects should consider the problem of natural ecological restoration at the end of the project and conform to the concept of whole-life management of engineering projects.

Dynamic functions include material circulation, energy conversion, and information transmission. 1) Material circulation: The material cycle is not closed and exists in the whole project ecosystem. In the process of construction and operation of large-scale public projects, a large number of materials are needed to form the entity of the project. As the material cannot be used completely, a large number of wastes will be generated. 2) Energy conversion: In the ecosystem of large-scale public projects, energy flows according to human purpose and behavior demand direction, and forms an engineering entity with material data, thus forming an artificial ecosystem. 3) Information transmission: The construction of engineering projects involves all aspects of society, and a lot of information will be generated in the process of project work and organization communication. The smoothness of information transmission determines the success or failure of the project, even the coordination of the whole project ecosystem.

Ecological engineering takes “integration, coordination, circulation, and regeneration” as the core, which is an important means of sustainable development of the ecosystem [4,5]. Urban ecological management contributes to low-carbon transformation and regional sustainable development [6]. The study of large-scale public projects is the specific application of ecological engineering in engineering projects. The goal is to realize multi-level and circular utilization of resources, promote the virtuous cycle of natural and artificial systems, which keeps the dynamic balance and coordinated development between large-scale public projects and economy, society and natural environment, so as to realize synchronous development of economic and environmental benefits [7]. The nonlinear thinking mode, system pipeline, and integrity theory of ecology provide a theoretical basis and a new way of thinking for solving the uncoordinated problems between large-scale engineering projects system, social system and natural system, which has important practical significance for the project itself, society, nature and other aspects. At present, the research on this aspect at home and abroad is not enough, and it is still in the exploratory stage. The paper focuses on the difficulties and challenges in the construction and management of public projects in China, and based on the specific project implementation situations such as Chinese unique political system, economic system, construction management system, and engineering culture, constructs the theoretical model of low-carbon production behavior of public projects and identifies its multi-dimensional structure, with a view to provide guidance and theoretical support for the practice and model development of public projects in China.

3. Attribute characteristics of low-carbon production behavior in public projects

According to the biological point of view, the relationship between organisms in the ecosystem is not only a competitive relationship but also a symbiotic relationship. In the engineering project ecosystem, symbiosis is the main relationship and driving force for the existence, development, and evolution of the whole system, especially in the aspects of information sharing and waste utilization and treatment. There are three kinds of behavioral basic components in the natural ecosystem: producer, consumer, and decomposer. Corresponding to the natural ecosystem, according to the principle of the engineering project ecosystem, the composition of the engineering project ecosystem can be divided into resource exploiter, manufacturer, and processor.

Engineering project ecosystem is an artificial ecosystem with multiple actors and complex components. Its evolution and system balance is a process from low order to high order, from simple to complex, from imperfect to gradually perfect. Constantly adjusting functions to meet the human needs, following the changes in the external social and economic environment and the continuous updating of the entity and technology of the project can reflect the complexity of the project system and the project itself. From the physical form of the construction project, the project has been completed, and the structure will not change generally. However, in the time scale of the whole life cycle of the project, function and structure should be interdependent. Due to the continuous adjustment of functions, the structure changes eventually, which are manifested as the renewal of engineering projects and sustainable service.

Ecological balance is the display of homeostasis in the ecosystem. Each ecosystem operates under the pressure of both internal and external factors. With the different scope of the system, the definition of internal factors is also different. The power of the project ecosystem is human, and the behavior subject is also human. The construction of engineering projects is to meet the needs of people. At the same time, the population factor is also the fundamental factor restricting and regulating the ecological system of engineering projects.

Large-scale public projects should meet the three basic attributes of sustainable development (spatiotemporal, harmonious, and cyclical), reflect the requirements of five relationships (human land relationship, interpersonal relationship, intergenerational relationship, interregional relationship, and international relationship), coordinate three benefits (social, economic and ecological benefits), and meet the three major civilizations (ecological, material and spiritual civilization). In order to meet the above requirements, on the one hand, large-scale public projects should be able to make a long-term contribution to the sustainable development of the city/region on the external attribute. On the other hand, in the internal attribute, the project itself must be constantly improved and expanded with the progress of the times and the development of science and technology.

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Each stage of the whole life cycle of large-scale public projects, from the planning and design, construction, operation, and demolition stages, will have an impact on its sustainable development and make it continuously improved. Table 1 summarizes the realization modes of sustainable development in various stages of public works

Table 1 The realization mode of sustainable development of public projects

Stage	Characteristic
Planning and design stage	The function can not only meet the current needs but also meet the needs of sustainable development goals of the project service area. This is reflected in the growth of population, the change of population structure, the need for economic growth, and the restriction of resource endowment. It can't blindly pursue ahead of time, but moderate advance, scientific advance, and should have room for development.
Implementation stage	Creation and management of a healthy building environment based on efficient resource utilization and ecological principles.
Operation stage	Cleaner production should be realized, especially the application of new clean recycling technologies and environmentally friendly materials. The goal is to minimize the impact on the environment and minimize life cycle costs
Demolition stage	Use the recycling method to realize the closed-loop circular movement of the material flow and energy flow of the project, and realize the circular economic development mode.

4. Multi-dimensional identification of low-carbon production behavior in public projects

Table 2 The main principles of scale design

Number	Principle	Requirement
1	The principle of meeting research needs	On the one hand, the designer is required to fully consider the research purpose and collect the required information as much as possible. On the other hand, the designer is required to accurately understand the research purpose and convert the measurement indicators into appropriate questions in the questionnaire.
2	The principle of considering respondents	The educational level of the respondents needs to be considered.
		The language habit of the respondents needs to be considered
		The cultural and psychological background of the respondents needs to be considered.
		Avoid designing long and complex questionnaires.
		It is necessary to keep the questionnaire simple and clear.
		Try to avoid designing too many complex recall problems.
3	The principle of combining with the data analysis method	The designer of the questionnaire should make clear whether the survey data are analyzed by hand or by computer.
		The designer of the questionnaire should make clear whether the survey data is mainly quantitative analysis or qualitative analysis
		The designer of the questionnaire should make clear whether the survey data are simple descriptive statistics or complex statistical analysis.
4	The principle of considering the specific investigation methods	There are more strict requirements for the questionnaire, the letter to the investigator, the guide for filling and answering, the number, expression, and arrangement of the questions.

The multi-dimensional identification and verification of low-carbon production behavior in public projects are scientific, which is affected by sample selection,

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statistical means, and the quality of researchers. Among them, the level of questionnaire design is a key prerequisite. It should be able to highlight the key points, put forward exact questions, correctly reflect the purpose of the survey, and make the respondents willing to cooperate and reflect accurate information. Based on the existing research, in order to ensure the reliability and validity of the research, the scale design mainly follows the following principles shown in the Table 2.

The research content of this chapter follows the principle of questionnaire design. The questionnaire is based on a large number of literature research results, combined with practical experts' interviews and academic in-depth interviews, and uses small sample pre-test and large sample data empirical analysis.

At present, there is no widely accepted measurement scale for the low-carbon production behavior of public projects in academia and project management practice. Therefore, a correct understanding of the construction dimension of low-carbon production behavior of public projects is helpful to deepen the research and measurement of the multi-dimensional structure of low-carbon production behavior of public projects.

Through the series of structured research work displayed in the Figure 2, the research content of low-carbon production behavior of public projects has been comprehensively interpreted. The paper uses content analysis method to extract analysis materials to design the analysis dimension, and finally obtains the analysis dimension describing the low-carbon production behavior of public projects. It can be summarized into three aspects qualitatively: project economic performance dimension, project social performance dimension and project environment performance dimension, as shown in the Figure 3.

(1) Project economic performance dimensions: national macro development policy, tax policy; life cycle cost (project budget, investment and financing channels, project investment plan); life cycle income/profit (financial risk assessment, investment recovery rate, net present value, payback period, internal rate of return); project technical method advantages.

(2) Project social performance dimension: the impact on the regional economic and social development (such as the improvement of income and living standards); the ability to promote social development, provide employment opportunities, and provide supporting facilities for other local economic activities; project safety, improvement of public hygiene environment and health, protection of cultural and natural heritage related to the project; land consumption and its impact.

(3) Project environment performance dimension: ecological impact assessment of the project, changes in environmental geographical characteristics; ecological environment sensitivity of the project; possible natural disasters or disease infection caused by the change of environmental geographical characteristics; air and water impact assessment (potential air and water pollution), noise and waste pollution of the project; the impact of the project on public health during construction and use; energy-saving and water-saving performance evaluation (application of energy-saving technology); environmental protection education.

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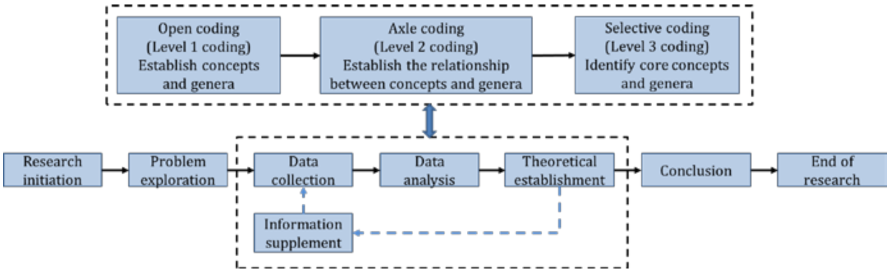

Figure. 2 Dimension construction of structural research procedure for low-carbon production behavior of public projects

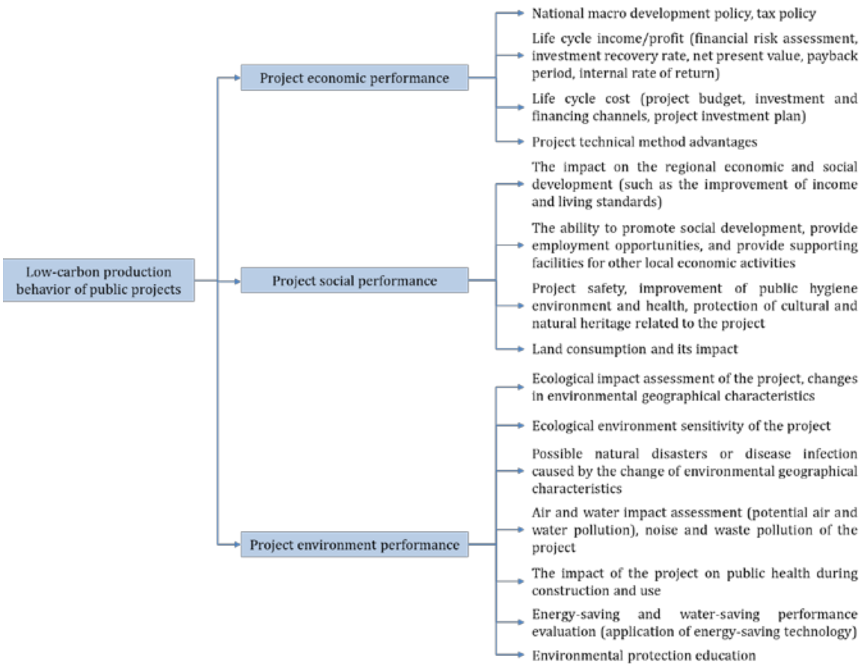

Figure. 3 Deduction and induction of low-carbon production behavior dimension of public projects

5. Factor analysis of low-carbon production behavior in public projects

Through a small sample survey (132 questionnaire data), exploratory factor analysis is conducted to identify the component dimensions of low-carbon production behavior of public projects. Firstly, the feasibility of the method is tested.

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According to Table 3, the KMO value test and Bartlett's test of sphericity are both passed, which indicates that it is suitable for factor analysis.

Table 3 KMO and Bartlett's measurement of low-carbon production behavior in public projects: sphericity test (n = 132)

KMO		0.874
Bartlett's test of sphericity	Approx. Chi-square	1.64
	df	193
	Sig.	.000

According to the results shown in the Table 4, Table 5 and Figure 4, the initial clauses of the multi-dimensional concept of low-carbon production behavior in public projects have been verified.

Table 4 Factor loading of exploratory factors for low-carbon production behavior in public projects (n = 132)

Dimension factor	Item	Factor loading			
		1	2	3	4
Factor 1: project economic performance	A1	.732	.868	.721	.721
	A2	.697	.684	.721	.721
	A3	.545	.732	.868	.721
	A4	.697	.697	.684	.721
Factor 2: project social performance dimension	B1	.721	.545	.689	.721
	B2	.721	.721	.721	.721
	B3	.732	.868	.721	.721
	B4	.697	.684	.721	.721
Factor 3: project environment performance dimension	C1	.545	.545	.689	.545
	C2	.721	.741	.731	.715
	C3	.721	.868	.721	.868
	C4	.721	.545	.689	.545
	C5	.723	.721	.731	.741
	C6	.741	.743	.724	.725
	C7	.742	.744	.751	.765

Table 5 Total variance explained of exploratory factors in low-carbon production behavior of public projects (n = 132)

	Initial eigenvalue			Rotation sums of squared loading		
Factors	Total	Population variance ratio	Cumulative variance ratio	Total	Population variance ratio	Cumulative variance ratio
1	8.476	39.663	47.458	3.835	31.486	44.317
2	4.343	33.452	49.685	3.647	28.672	53.325
3	5.246	24.533	53.534	3.474	33.453	55.534

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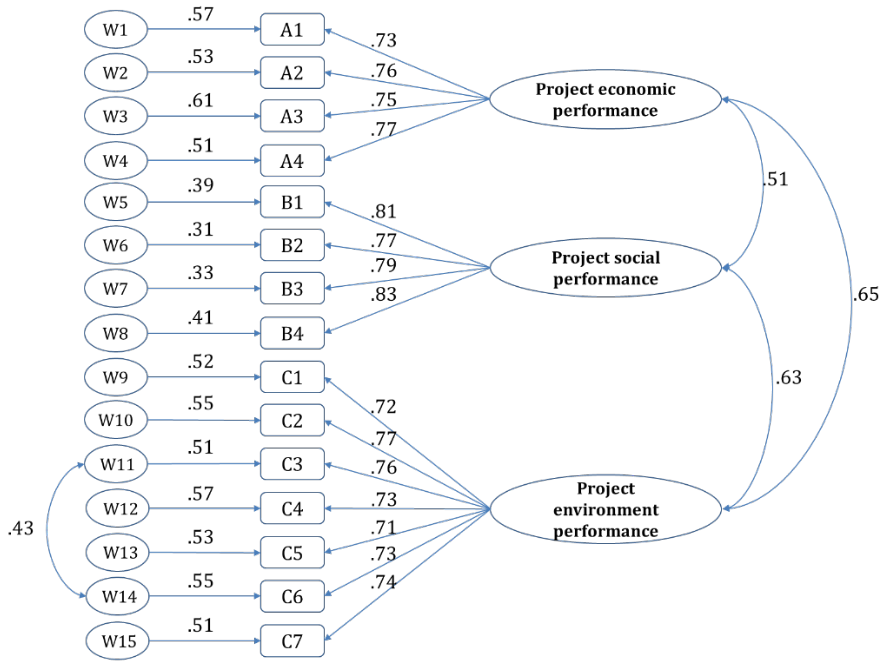

Figure. 4 Confirmatory factor analysis (CFA) and the standardized path coefficient of low-carbon production behavior in public projects

6. Reliability and validity analysis and overall fit evaluation of large sample data

The formal large sample questionnaire survey lasted about 207 days. During this period, 341 questionnaires were distributed through various channels, and 273 questionnaires were recovered. The recovery rate of the questionnaire was more than 80%. After the questionnaires were collected and checked, 15 invalid (or important information filled in incorrectly and unable to be verified by follow-up visit) questionnaires were eliminated. Finally, 258 questionnaires were obtained for analysis and research. In order to ensure the reliability and validity of the public projects' low-carbon production behavior scale, this study uses SPSS and AMOS software to test and evaluate the scale.

(1) Internal consistency reliability

Through the test and analysis of large sample measurement data, confirmatory factor analysis meets the standard, indicating that the measurement questionnaire meets the standard requirements of internal consistency reliability.

(2) Construct reliability (CR)

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Through the analysis of the construct reliability (CR) of each dimension of the construct, the calculation results show that it meets the requirements (CR > 0.6).

(3) Content validity (or logical validity)

Through reference to literature, expert interviews and research, small sample pre-test, the appropriateness and consistency of the measurement content are ensured, and the content validity is appropriate.

(4) Construct validity

The construction validity generally judges the convergence (aggregation) validity by calculating the average variance extracted (AVE) of each dimension and calculates the root mean square of AVE value of each dimension to judge the discriminative validity of the questionnaire. The calculation results show that the convergence (aggregation) validity of the three dimensions meets the requirements (AVE > 0.5), and the questionnaire has good discriminative validity.

The goodness of fit index ($\chi 2$/df, AGFI, GFI, NFI, IFI, CFI and RMSEA) is used as the indexes to test the fitting degree of model and data, and the main evaluation indexes of confirmatory factor analysis (CFA) are used to measure the overall fitting degree.

According to the specific standards verified by extensive academic measurement: $\chi 2$/df below 5, preferably below 3; AGFI and GFI above 0.85, preferably above 0.9; NFI, IFI, and CFI above 0.9, RMSEA below 0.1, preferably below 0.05[8]. According to the above tests, all the indicators meet the requirements of the standard, indicating that the model has a good fitting effect (good construction validity) and can be accepted (as shown in the Table 6 and Table7).

Table 6 Main indicators of confirmatory factor analysis for measurement of low-carbon production behavior in public projects

Index classification	Index	Value	Evaluation criterion	Whether the requirements are met or not
Absolute fitting index	$\chi 2$/df	1.573	Less than 5, preferably less than 0.05	Meet
	RMSEA	0.003	Less than 0.10, preferably less than 0.05	Meet
	AGFI	0.907	More than 0.85, preferably greater than 0.90	Meet
	GFI	0.913	More than 0.85, preferably greater than 0.90	Meet
Relative fitting index	NFI	0.917	More than 0.90	Meet
	IFI	0.901	More than 0.90	Meet
	CFI	0.952	More than 0.90	Meet

Table 7 Parameter estimation table of an overall measurement model for low-carbon production behavior of public projects

Factor	Item	Standardization coefficient (R)	T	R2	CR	AVE
Project economic performance	A1	.526	6.818***	.277	0.684	0.431
	A2	.552	7.262***	.305		
	A3	.843	8.047***	.710		
	A4	.793	9.040***	.629		
Project social performance dimension	B1	.650	7.168***	.422	0.717	0.393
	B2	.734	6.877***	.538		
	B3	.485	6.025***	.235		
	B4	.613	6.025***	.376		
Project environment performance dimension	C1	.397	4.941***	.158	0.588	0.369
	C2	.636	5.869***	.404		
	C3	.548	5.190***	.300		
	C4	.461	6.025***	.213		
	C5	.636	5.869***	.404		
	C6	.548	5.190***	.300		
	C7	.461	6.025***	.213		
The goodness of fit index:						
χ2/df	GFI	AGFI	NFI	IFI	CFI	RMSEA
1.573	0.913	0.907	0.917	0.901	0.952	0.033

7. Conclusion

This paper starts from the concept of low-carbon production behavior of public projects, bases on literature research results, combines with questionnaire survey and interview results, comprehensively and deeply analyzes and refines the structural dimensions of low-carbon production behavior of public projects, so as to extract three common factors which are project economic performance, project social performance, and project environmental performance. And then construct a three-dimensional framework of low-carbon production behavior of public projects including 15 key factors. This can deepen the understanding of the concept of low-carbon production behavior of public projects, and further study the mechanism between low-carbon production behavior of public projects and related variables, and provide a reference for the management of low-carbon production behavior of public projects.

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