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CHINA'S EXPERIENCE IN THE DEVELOPMENT AND APPLICATION OF CONSTRUCTION COST ENGINEERING

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Abstract

This paper provides an in-depth discussion of China's rich experience in the field of building cost engineering development and application, especially focusing on the current development of assembly building, which is the most representative of the process of building industrialization. With its relative advantages in cost, especially its wide application in the construction projects of sheltered housing, assembly building has gradually become one of the important directions for the transformation of China's construction industry. Despite the fact that assembled buildings have demonstrated many advantages, such as reducing on-site construction pollution and shortening the construction period, challenges in terms of low technological maturity, shortage of professionals, and cost control still exist. The article further analyses the concept of building industrialization and its impact on construction cost, pointing out that although the cost of industrialized housing may be higher in the use phase, its overall cost is lower and the economic benefits are significant from the perspective of the whole life cycle. In addition, a BP neural network model is introduced in the paper to predict the cost of assembled buildings. Through the learning and training of a large number of actual project data, the model demonstrates excellent prediction ability, which can effectively assist decision makers to make an accurate estimation of the project cost at the early stage of the project, reduce the project cost, and promote the healthy development of assembly buildings. Therefore, this paper not only provides valuable practical experience for the development of construction cost engineering, but also lays a solid theoretical foundation for the promotion and application of assembly building.

Keywords: building industrialization, prefabricated building, cast-in-situ building, BP neural network model.

ОПЫТ КИТАЯ В РАЗРАБОТКЕ И ПРИМЕНЕНИИ ИНЖИНИРИНГА СТОИМОСТИ СТРОИТЕЛЬСТВА

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Реферат

Данная работа представляет углубленное обсуждение богатого опыта Китая в области развития и применения строительства по проектированию затрат. Особое внимание уделяется текущему развитию монтажного строительства, которое является наиболее представительным в процессе индустриализации строительства. С учетом своих относительных преимуществ в затратах, особенно широкого применения в строительных проектах социального жилища, монтажное строительство постепенно стало одним из важных направлений преобразования строительной промышленности Китая. Несмотря на то, что монтажные здания продемонстрировали многие преимуществ, такие как уменьшение загрязнения на строительном участке и сокращение срока строительства, все же существуют проблемы в виде низкой технологической зрелости, недостатка специалистов и контроля затрат. Статья анализирует концепцию индустриализации строительства и ее влияние на стоимость строительства, указывая, что хотя стоимость индустриализированного жилища может быть выше на этапе эксплуатации, ее общая стоимость ниже, а экономические выгоды значительны с точки зрения всего жизненного цикла. Кроме того, в работе представлена модель нейронной сети прямого распространения (BP) для прогнозирования стоимости монтажных зданий. Через обучение и тренировку на большом количестве фактических данных проектов, модель демонстрирует отличную способность к прогнозированию, что может эффективно помочь принятию решений лицам, занимающимся принятием решений, точно оценивать стоимость проекта на ранней стадии проекта, снижать стоимость проекта и способствовать здоровому развитию монтажного строительства. Таким образом, данная работа не только представляет ценный практический опыт для развития строительства по проектированию затрат, но и создает прочную теоретическую основу для продвижения и применения монтажного строительства.

Ключевые слова: индустриализация строительства, сборное здание, монолитное здание, нейросетевая модель BP.

1 Introduction

The construction industry is one of the pillar industries of China's national economy, which has a significant impact on the country's economic form. Starting from the executive meeting of The State Council of China in 2016 to promote prefabricated buildings, various localities began to pave the way for the development of prefabricated buildings in terms of tax support policies. In 2017, China's Ministry of Housing and Urban-Rural Development issued the "13th Five-Year Plan" Action Plan for prefabricated buildings. The plan clearly indicates that more than 15 % of the regions that are expected to actively promote prefabricated buildings by 2020, and the number of buildings should also exceed 15 % [1]. According to the Consumption Quota of prefabricated Construction Projects issued by the Ministry of Housing and Construction of China, for prefabricated residential projects, the construction cost of low-rise buildings is about 2150 RMB/m^2 (equivalent to 306.66 USD/m^2), and the construction cost of high-rise buildings is about 2420 RMB/m^2 (equivalent to 345.17 USD/m^2). The construction cost of the cast-in-place concrete building estimated by the Ministry of Housing and Urban-Rural Development is about 2000RMB/m^2 (equivalent to 285.26 USD/m^2) [1].

2 Industrialization of building

2.1 The concept of building industrialization

The United Nations Economic Commission has put forward the relevant concepts of building industrialization, namely: continuity of production, standardization of production materials, integration of various stages of production process, mechanization of construction, highly organized engineering, integration of production and organization. The industrialization of construction is summarized in one sentence, which is to organize

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the production of houses like the manufacture of cars [2]. Prefabricated building is a special building technology system that elevates all kinds of general prefabricated components (PCS) to factory production and on-site mechanized assembly through proprietary connection technology. Prefabricated building is a representative product of building industrialization, which is widely used in affordable housing, and is a development trend of future construction projects. Its advantages are short construction period, less pollution in site construction, and less restriction by climatic conditions. Precast concrete components generally refer to building components pre-made by concrete, which is the basis for realizing the prefabrication of the main structure. Its main advantages are good structural properties, pipeline-type factory production can efficiently ensure structural mechanical properties, strong cohesion. However, because the whole performance of precast concrete is not ideal in practice, it can not be used in buildings with high seismic requirements [4].

2.2 The concept of engineering cost

Project cost refers to the costs required in the process of project construction, including land costs, design costs, construction costs, material costs, equipment costs, management costs, supervision costs, etc. The calculation of project cost needs to consider the rationality and economy of various costs to ensure the quality and efficiency of the project. In the early stage of the project, it is necessary to carry out budget and cost control to evaluate the feasibility and rationality of the project. In the construction process, it is necessary to carry out cost management and cost control to ensure the construction progress and quality of the project, and to maximize cost savings. From the perspective of the owner, the project cost refers to the total amount of all actual costs incurred by a project from scratch to fully complete the construction of the project, that is, all fixed asset investment costs [5].

2.3 The influence of building industrialization on project cost

In terms of the impact of construction industrialization on project cost, the cost of industrial housing is higher in the use stage, but its whole process cost is lower than that of traditional housing. In terms of the influence of prefabricated construction on project cost, prefabricated construction is at a disadvantage in installation projects and needs to be improved [6]. The large scale of enterprises, only have the strong strength to carry out relevant scientific research, easy to reach cooperation with relevant suppliers, and then make the standards of enterprises become the standards of the supplier industry, and drive the industrialization process of the entire industry.

3 Cost of prefabricated construction project

3.1 The position of prefabricated construction in building industrialization

Prefabricated construction is an important construction technology in building industrialization, and its application in China is mainly concentrated in affordable housing, and prefabricated construction technology has been greatly developed in this process. With the continuous development of technology, such as PC integrated assembly construction, the principle of systematics is used to consider the unity of the position of prefabricated steel bars and reserved steel bars, and the straight thread composite connection is used to connect the components. The integral cast-in-place method is adopted at the joint, which has good seismic performance and overall performance, and gradually overcomes the problems of instability, water leakage and component shedding in the assembled construction technology [6].

3.2 Comparative analysis of the cost of prefabricated buildings and cast-in-place buildings

Take Building 3# of Country Garden Peoples Project in Ningbo City, China as an example, its construction area is 4714 m^2, according to relevant drawings and standard specifications, in accordance with the same quality requirements and functional standards. According to the four types of projects, the total cost of prefabricated construction and cast-in-place construction is analyzed, as shown in Figure 1.

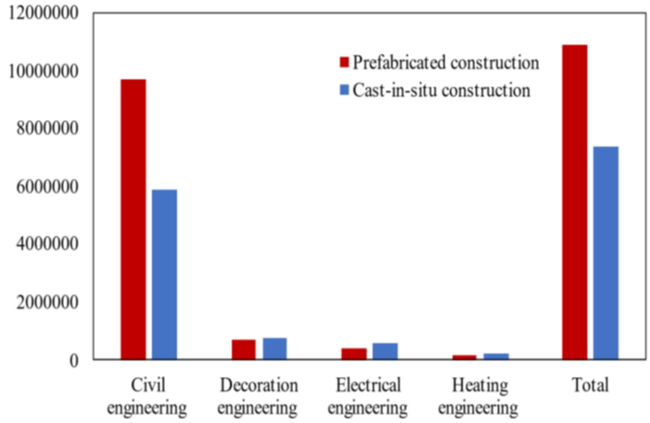

Figure 1 – Comparison of total cost of prefabricated construction and cast-in-place construction

It can be seen from the figure that the cost of prefabricated construction is higher than that of cast-in-place construction except for civil engineering, and all other projects are lower than that of cast-in-place construction [8]. Because the cost of civil engineering of prefabricated construction is much higher than that of cast-in-place construction, the prefabricated construction is in a disadvantageous position compared with cast-in-place construction in total price.

4 Cost estimation of prefabricated construction project based on BP neural network

4.1 Project introduction

This paper selects China's Ningbo Country Garden People Project, which covers an area of 69240.67 m^2 and a building area of 167080.99 m^2, among which the built-up area is 124633 m^2, and the building density, plot ratio and greening rate are 29.31 %, 1.8 and 30.15 %, respectively. The prefabricated project planning is shown in Table 1 [9]:

Table 1 – Prefabricated project planning scheme

Implementation plan	Building number: 5#, 11#, 15#	Implementation scale: 22,800 m^2
Structural system	Prefabricated shear wall structure system	Internal casting and external hanging system
Precast component	Prefabricated cladding (including insulation)	Prefabricated shear wall external wall (including insulation)
	Prefabricated balcony	Prefabricated air conditioning panel
Built-up interior	High precision block + thin plaster	Package window system
Construction technique	Tower crane selection: Heavy tower crane	Formwork: Wood formwork
	Use penetration construction techniques: Yes	Scaffold project: self-lifting climbing frame

4.2 Analysis of the actual project cost

The installation cost of prefabricated components is determined by the general contractor according to the group price of construction site consumption and scheme, etc., and the unit price of all installed prefabricated components is determined after negotiation [9]. The unit price of installation consists of embedded iron parts, on-site unloading of components, construction of high-strength grouting materials, joint treatment, cleaning of exterior wall parts and gluing treatment, etc. The above are all processes of installation of prefabricated components. The non-component parts of the prefabricated component cost include the on-site installation cost and the purchase of the main materials of the prefabricated component [10]. All price details are shown in Table 2.

Table 2 – Valuation table of component engineering quantity list

Project	Unit	Quantity of work	Comprehensive unit price	Main material price	Total
PC straight wall	m^3	300.7	865	2900	1132135.50
PC bay window	m^3	94.99	890	3600	426505.10
PC balcony	m^3	68.79	930	3380	296484.90
PC stairs	m^3	61.37	940	3100	247934.80
Total	RMB				2103060.30

Underground engineering below 0 meters mainly refers to the construction of basement engineering, pile foundation engineering, etc., which will not affect the cost level of the study of assembled engineering, so the underground engineering part will not participate in the study of this paper. The unit project cost summary shows the itemized cost of each project, and the total project cost includes taxes and fees [11]. According to the statistics and summary analysis of the actual engineering data, the total cost of building 5# using the prefabricated construction method is about 8.2 million RMB, and the single cost is 1064.28 RMB per square meter after conversion, including the incremental cost of structure and construction measures. The unit cost of the project is shown in Table 3.

Table 3 – Summary of project unit engineering cost

Number	Project	Cost
1	Total value of bill of quantities	6073660.78
2	Structure and rough decoration	3946173.98
3	Below 0.00	0.00
4	Above 0.00	2768161.50
5	Facade decoration	24426.50
6	PC prefabricated installation (including main materials)	2103060.30
7	Measure project cost 1 (Formwork scaffold)	1526847.08
8	Measure project cost 2 (except formwork scaffolding)	607746.58
Total		8208254.43
Floor area		7712.52 m^2
Project cost alone		1064.28 RMB/m^2

4.3 BP neural network model construction

The basic structure of BP neural network includes input layer, hidden layer and output layer. The structure design of BP neural network estimation model for prefabricated building engineering will focus on these three aspects, including the number of neuron nodes in input layer, hidden layer and output layer [13].

The input layer is the model that receives information and transmits it to the neurons of the next layer. Starting from the basic principles followed by the cost budget of prefabricated building projects, the most direct factors affecting the cost are selected as the key feature indicators. The direct feature factors affecting the project cost include inner wall, outer wall, column, beam, plate, staircase and balcony bay window [13]. The corresponding input index of the training sample is the prefabrication rate of each prefabricated component and the unilateral incremental value, with a total of 9 data. The purpose of the calculation model is to calculate the unilateral building cost index of the target project according to the known prefabrication rate, so the indicator data to be input for the target project to be estimated is only the prefabrication rate of each prefabricated component, with a total of 8 data [15].

Hidden layer design includes layer number design and node number design. The hidden layer is the middle part of the neural network estimation model, and its role is to process and transform information. According to the needs of actual problems, the hidden layer can be designed as a single-layer hidden layer or multi-layer hidden layer structure. This function is a continuous function in the definition domain, and it is a suitable activation function for prefabricated construction cost estimation model [16]. Therefore, it is only necessary to adopt a single hidden layer structure in the design of network structure. The setting of the number of nodes in the hidden layer mainly considers the nature and characteristics of the training samples, including the number of training samples, the proportion of non-regular content in the samples and the complexity of regular content in the samples. For more complex nonlinear functions, due to their frequent fluctuations and large amplitude changes, more neuron nodes in the hidden layer are needed to enhance the mapping ability of the network [17]. For linear functions, in general, the setting of the number of hidden layer neurons can be determined by empirical formulas, which are commonly used as shown in equation (1). Where n represents the number of neurons in the hidden layer, m represents the number of input data, and l represents the number of neuron nodes in the output layer. When the model is trained, the number of neuron nodes in the input layer is 6, and the number of neuron nodes in the output layer is 1, then the number of neuron nodes in the hidden layer is 2 according to the formula [18].

$$\begin{cases} n = log2^{m} \\ n = \sqrt{ml} \end{cases} \#. \quad (1)$$

The output layer is the result value measured by the model system, which represents the functional goal to be achieved by the system, and is also the only condition for error determination. In this model, we hope to predict the unilateral cost and other cost indicators, and the output result is one of the unilateral cost of the prefabricated building [19].

4.4 Prefabricated building cost calculation

Twenty groups of data from 25 residential engineering samples in Zhejiang, Shanghai and Jiangsu from 2017 to 2020 were randomly selected as training sets and input into the constructed BP neural network prediction model to complete the training. On this basis, a prefabricated construction cost prediction model based on BP neural network is successfully established, and the training data are shown in Table 4 [20].

Create a feature variable array and a predictor variable array respectively in MATLAB, and import the data into the BP neural network model. The model structure is shown in Figure 2.

Table 4 – Training data

Number	Bearing wall	Column	Beam	Non-load-bearing wall	Plate	Precast rate	Incremental cost (RMB/m²)
1	0 %	0 %	0 %	0 %	5.46 %	14.46 %	254
2	0 %	0 %	0 %	0 %	6.3 %	15.3 %	260
3	0 %	0 %	0 %	0 %	10.29 %	19.29 %	289
4	0 %	0 %	0 %	0 %	12.6 %	20.1 %	283
5	6.8 %	0 %	0 %	0.82 %	12.6 %	29.22 %	401
6	15.3 %	0 %	0 %	1.8 %	3.36 %	29.46 %	454
7	15.81 %	0 %	0 %	1.8 %	12.6 %	39.21 %	527
8	11.9 %	0 %	0 %	1.44 %	16.8 %	39.14 %	503
9	8.33 %	8.7 %	10.5 %	0 %	12.6 %	49.13 %	636
10	15.47 %	16.24 %	0 %	1.86 %	16.8 %	59.37 %	758
11	15.47 %	0 %	15.75 %	1.8 %	16.8 %	58.82 %	729
12	0 %	0 %	0 %	2.7 %	6.86 %	20.6 %	319.5
13	10.89 %	0 %	0 %	0 %	7.53 %	20.32 %	262.8
14	5.01 %	0 %	0 %	5.05 %	6.72 %	30.76 %	452.7
15	14.1 %	0 %	0 %	3.09 %	7.3 %	30.25 %	386.1
16	11.82 %	0 %	0 %	7.03 %	6.56 %	39.7 %	606.6
17	9.24 %	0 %	0 %	1.65 %	0 %	19.17 %	220.78
18	8.4 %	0 %	0 %	1.87 %	0 %	19.89 %	225.76
19	6.3 %	0 %	0 %	0 %	4.8 %	20.72 %	173.82
20	10.5 %	0 %	0 %	1.1 %	4.8 %	19.38 %	209.18

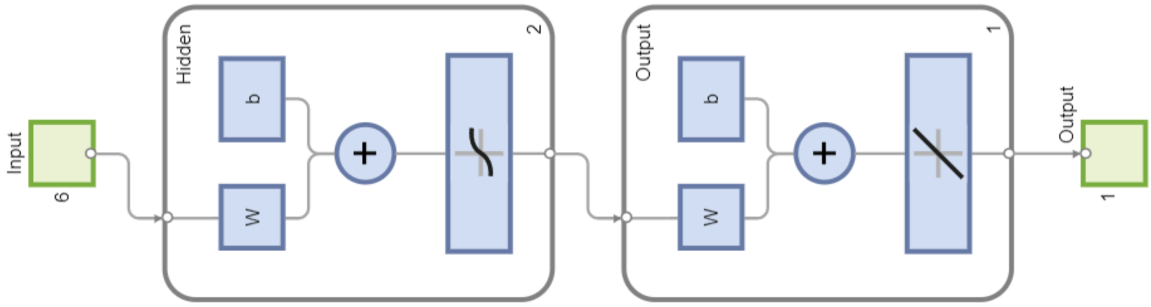

Figure 2 – Structure diagram of BP neural network

Then, Levenberg-Marquardt method is used for training, and the effect of the prediction model is analyzed according to the training performance graph and regression graph. The training performance diagram is shown in Figure 3, where the blue solid line represents the training process of the neural network, and the green solid line represents the verification process of the neural network. The red implementation is to test the neural network process and show the change of the MSE value. The Best dashed line represents the best result of the neural network after training to the 13th time.

The fitting of model training is shown in Figure 4. The fitting degree between the model output data, training data, verification data and test data is above 0.8, indicating a high degree of linear correlation, indicating that the model has a good prediction effect and can predict the cost of prefabricated buildings.

Based on MATLAB software, this paper establishes the prefabricated construction project evaluation model by combining the principle of BP neural network with the cost characteristics and engineering characteristics of the prefabricated construction project. The real case data is comprehensively collected, the database is built to simulate the model, and the predicted cost estimate value is adjusted and corrected after the training, so as to improve the rationality and accuracy of the estimate, so as to be consistent with the real project construction, and finally the estimate model of unilateral project cost increment can be used in engineering practice.

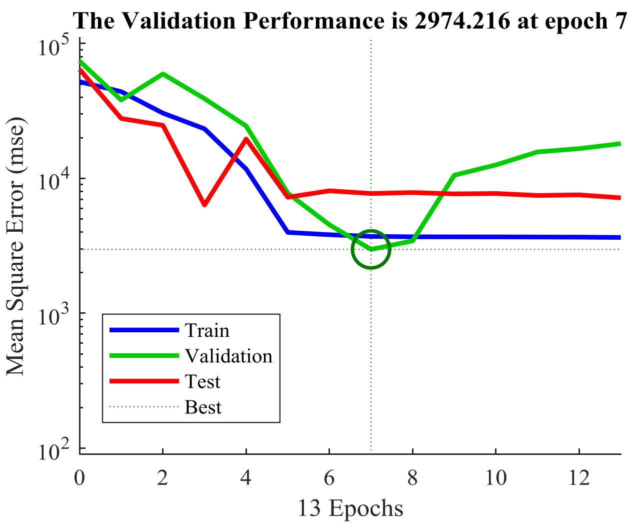

Figure 3 – Training performance of BP neural network model

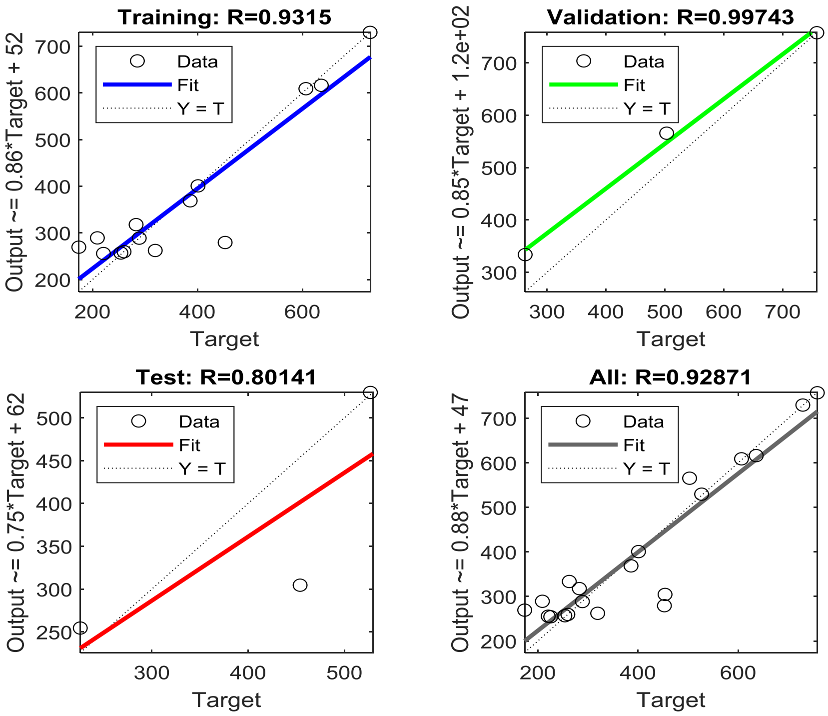

Figure 4 – BP neural network model training regression diagram

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