Research Article

Evaluation Model for Spatial Allocation Efficiency of Modern Educational Campus Building Using Big Data

Lan Zhou and Yang Lu

1School of Architecture, Xi’an University of Architecture and Technology, Xi’an 710000, China
2School of Economics and Finance, Xian Jiaotong University, Xi’an 710000, China

Correspondence should be addressed to Lan Zhou; zhoulan@nwpu.edu.cn

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Abstract

With the continuous development and improvement of university education, providing students with refined and comprehensive learning environment has come to be a problem of great importance and significance to the people. The state carries out quality-oriented education through a series of measures of education reform. These measures and standards not only help to improve the overall quality of students, but also put forward higher requirements for planning and architectural design of university campuses. In fact, the development of university campuses has been severely restricted by serious contradictions between the shortage of urban construction land and the expansion of middle school campuses. Therefore, in the case of limited construction land resources, how to integrate and optimize the building space and function of campus, improve the utilization rate of building space, make full use of the limited construction land, and create a rich and diverse space environment are difficult problems that are faced in the design of today’s universities. In this paper, we discuss the integration strategy of main entrance space of university campus city through empirical research and put forward 4 value evaluation dimensions and 24 value evaluation factors. Moreover, we construct a numerical and geometric evaluation model, i.e., “CPCC,” to complete the evaluation and optimization of the integration strategy. The purpose is to provide reference for the research object and same type of space on the interface of university campus city.

1. Introduction

The university campus city main entrance space is an important part of college campus city interface. This area is not only the iconic areas that show the campus landscape, but also a university academic culture and social business service atmosphere of the centralized fusion point and interface [1]. The composition form, economic structure, and transportation mode are affected by the action of the city and the university at the same time. Currently, for the university city, the university city main entrance space is not an independent function structure, in the urban planning and urban design. Similarly, it is also often only a node simplified into a single entry and square space pattern. Moreover, for the campus space and city space collocation, composite and seepage influence each other and positive significance is the lack of attention and thinking. In the process of rapid urbanization, universities and cities are facing the historical opportunity of integration and symbiosis. How to avoid negative factors and stimulate positive factors in space construction has become an important topic in the development of university and city interoperability. In this paper, we will complete the integration and optimization of the main entrance space of the university campus city from the aspects of spatial structure, functional composition, spatial form, and spatial elements by means of a case study, integration strategy analysis, and construction of an evaluation model. Finally, we will establish the corresponding evaluation system and working method.

In terms of technical route, this paper focuses on the extraction of typical problems in specific space types, expounds the problems from four aspects of (i) spatial
structure, (ii) functional composition, (iii) spatial form, and (iv) spatial elements and puts forward several integration strategies for comparison and optimization. The integration strategy is put forward from two aspects. One is to review and reflect on the historical origin of the space prototype. The second is to look forward to the future and explore certain forward-looking strategic choices. On this basis, through combining with the value of two-way between university and city, we evaluate the applicability of the integrated strategy and the match analysis. Then, we set up the integration of specific evaluation value dimension and value evaluation factors, through building the appraisal model of numerical evaluation model and geometric intuitive. The model is verified with different integration strategies of evaluation, comparison, and optimization.

Most of the urban main entrance space of university campuses in China has obvious axis control characteristics. However, there are relatively few examples of free layout. Taking 72 universities in Beijing, as an example, only 17 universities adopt nonaxis control layout of main entrance space, and most of them are due to the limitation of space. As far as the main entrance space of the city is concerned, the space type of the university campus, which is mainly axis, can be divided into axis, aggregation, and introversion. In addition, a variety of forms, such as group cluster type, and the counterpoint to axis-type structure mode as the main body, such as the eight major schools of Beijing campus main entrance space, are used for the spatial organization form [2]. Therefore, considering the limited space, and the space for various types of integrated strategy one by one, this paper will combine the specific space prototype [3]. Moreover, the paper analyzes the most extensive common large scale and the axis of the memorial, ceremonial strongly para campus main entrance space, and discusses the space and city space integration strategy and evaluation system [4]. The following are the major contributions of the research conducted in this manuscript.

1. We discuss the integration strategy of main entrance space of university campus city through empirical research.
2. We put forward 4 value evaluation dimensions and 24 value evaluation factors, and construct a numerical and geometric evaluation “CPCC model” on this basis to complete the evaluation.
3. We provide a reference for the research object and the same type of space on the interface of university campus city and effectively promote the historical process of the integration between university campus and city.

The remaining of the paper is structured in the following manner. In Section 2, we discuss the problem, analyze the problem, and offer an overview of the related work. In Section 3, we demonstrate the basic concepts used within the paper. The data envelope analysis (DEA) method is also explained. Evaluation model construction and the proposed model are discussed in Section 4. Experimental outcomes are elaborated in Section 5. Finally, Section 6 summarizes the paper and offers several directions for future research.

2. Related Work

The main entrance space of Chinese university campus adopts the design method of large scale and axis symmetry, which originated from the Soviet Union, and pursues the commemorative and ceremonial nature. Most of them are modeled on the main building of the new site of Moscow University completed in 1953 and the main entrance space of the campus in front. Then, half a century later, through the case study of the renovation practice of the main entrance space of Moscow University today, we might provide reference for the optimization and integration of the main entrance space of campus in China. When it is imitated and referenced by Chinese universities, the three elements of its main space are the long axis and the height (240 m), which, respectively, correspond to the main building and the big square. However, in modern higher education and under the two-way objective demands of urban development, much of the spatial pattern also reflects and adjustment is made. The main performance is described as follows:

(i) The main body of the large space square has changed from single homogeneity to multiple heterogeneity. The original homogeneous whole is divided into five times squares through a central square. A four square surrounds the central square and is divided radially. For each outer circle, the square emphasizes its edges through green plants. Theme sculptures are set in the middle of the square to form a relatively independent sense of integrity [5].

(ii) From sacred scale to human scale: When the subject space changes from single homogeneity to multiple heterogeneity, the sense of scale of space changes accordingly. Through the cutting of the original square, multiple sub-large-scale spaces have replaced the single large-scale space. Meanwhile, the introduction of large-scale planting of different scales and the space enclosure formed by the rich scale have further changed the perception of the actual spatial scale of the crowd walking in the square [6]. The 240 m-high main building becomes the backdrop of multiple sites rather than the center, effectively eliminating the huge scale of the square, axis, and main building.

(iii) From rally inappropriate to diverse participation: Affected by socialist state ideology, site is designed mainly on the function considering the mass assembly. Therefore, in most of the time, site appears empty, in the doldrums. In addition, the 240 m-high Gothic memorial form of the main building takes the atmosphere of sacred worship to the extreme (it was once the tallest building in Moscow), and its symbolic expression far exceeds the consideration of its use requirements. Now, through the division and adjustment of the space, the pedestrian space with good continuity is embedded in the square, and the
square places seasonal green plants of different colors, shapes, and heights in this space to form a different space atmosphere and encourages the public to take a walk, rest, picnic, reading, gathering, and other activities [7]. It should be emphasized that the commemorative axis, as an indelible mark of the place and the memory of The Times, has been fully respected and retained in the abovementioned changes.

Mr. Robert Venturi, a famous American architect, is a world-renowned architect and architectural theorist. His firm, Venturi, Scott Brown, and Associates Inc. (hereinafter referred to as VSBA), has been engaged in the theory and practice of campus planning for many years [3]. In 2003, Mr. Venturi went to Beijing to accept the assignment of Tsinghua University campus planning revision consultation. In 2004, he and Mrs. Brown co-chaired the “Tsinghua University Campus Planning revision consultation report.” On the VSBA website, this project, along with Harvard Campus Planning and Yale Campus Planning, is one of the three key projects recommended by the portal interface of VSBA, which shows that VSBA attaches importance to and is satisfied with this achievement [4]. Among them, Mr. Venturi proposed the following ideas for the integration strategy of the main entrance space of Tsinghua University campus.

(i) Long-term improvement idea: the core concept of this idea is to subdivide the large lawn in front of the main building into multiple sunken squares to enrich the landscape level of the space while creating a relatively quiet space [8]. Around the sunken square, student activities and public service spaces will be placed. Under the square and service space, parking lots for bicycles and cars will be placed to solve the increasingly acute regional parking problems [9]. In addition, the concept of “layer" and "functional mix" was introduced to improve the area on both sides.

(ii) The skin features and usage of landscape, roads, and buildings: this solution is considered ideal by Venturi, but it requires a long time and economic cost to implement and cannot meet the immediate needs of the region [10].

(iii) Recent improvement idea: as an alternative, the core methodology of this idea is a sunken central plaza, with spaces for student activities and public services around Guangtang, while improving the use of landscape, roads, and buildings on both sides of the area [11]. This scheme has low economic cost and can be implemented in the near future, while preserving the possibility of long-term realization of the ideal scheme as investigated in [12].

In the construction of the evaluation model, the most important core idea is to take into account the two-way value appeal on the interface of university campus city. Moreover, promote the communication between city and campus, and promote the “opening” process of university campus. Starting from the four value dimensions 3–1, including constructing multiple order, promoting humanistic atmosphere, and improving urban landscape, evaluation factors are established in each value dimension (see Table 1) to evaluate the effectiveness of each integration strategy [13]. In the specific comparison process, according to the number of comparison strategies and the actual situation, the value interval is determined for the evaluation factor, and the size of the interval is aimed at differentiating the comparison strategies. The more integration strategies enter the comparison; the value of the interval will increase and vice versa. The value is a qualitative value for horizontal comparison, which only has relative comparison significance, rather than the absolute value.

Considering the specific one integrated strategy on the perspective of the value of impact, they are not balanced and even limit the influence of the way. This happens often in a different perspective of the value of reciprocal situation, rather than as a single. This can be resolved through promoting or weakening the effect of an average 15, for example: the VSBA long period improved vision, into a large amount of public service function sinking [14]. The construction of square contributes to the diversification of function composition in J2Y1-main entrance space, J2Y2-main entrance space in the form of the degree of diversification, and other aspects of positive impact and role. However, in the J3Y5-main entrance space in the control of the commercialization function of the market, there are obvious hidden dangers. In addition, there is a huge risk that may lead to complete commercialization of the area. Therefore, it is considered to establish the “cross-axis range evaluation model” and comprehensively evaluate the status quo or the overall value of each integration strategy through the determination of the comprehensive range of each integration strategy [15]. Ideally, the CPC model at each end of the intersection is the maximum and the optimal solution, so the interconnection closed region formed by the four axial apoapsis quadrilaterals is also the maximum. Nevertheless, in the actual operation process, obviously, in every value point of view there is no perfect integration strategy, and each range of values of the integrated strategy can infinitely tend to be ideal. Therefore, the value cannot be reached as quickly as needed. However, the approaching ratio can measure the value level of different schemes and determine their development potential and space for optimization purposes, accordingly.

3. Basic Concepts

3.1. Definition of Efficiency in Construction Industry. At present, the efficiency of the construction industry can be well understood from two perspectives: (i) one is the labor productivity of the construction industry, and (ii) the other is productivity of the construction industry. This should be noted that the former refers to the output value created per capita per unit time in the construction industry, and the final evaluation result is a specific value. Similarly, the latter refers to the ratio of the upper limit of actual output and
expected output under the condition of given input, and the final evaluation result is also a specific value. They are all units of measurement, and they are not 100% efficient in construction [16, 17]. As can be seen from the above definition of efficiency, efficiency in the construction industry is a multivariate concept, which includes not only productivity, but also technical efficiency and allocative efficiency [11, 18].

In view of this, this study defines the efficiency of the construction industry as follows: the overall efficiency including productivity, technical efficiency, and allocative efficiency, and the proportion relationship between the construction industry input and output under the corresponding market conditions. From the perspective of input, the ratio between the minimum cost and the actual cost is required to achieve the maximum cost condition under various production technology conditions without considering the effect imposed by market environment. The evaluation is based on the output perspective, without considering the effect imposed by the market environment, and the ratio between the actual output and the ideal output under various production technology conditions [5, 19, 20].

### 3.2. Evaluation Methods

In recent years, domestic scholars have made a great deal of analysis and discussion on the efficiency of the construction industry in China and achieved many achievements. At present, a certain number of evaluation theories and operation techniques have been put into practice. Based on the analysis of a series of existing literature on efficiency evaluation of domestic construction industry, this paper concludes five evaluation theories: (i) diamond theory; (ii) sustainable development theory; (iii) environment and market conditions; (iv) logical framework method; and (v) production frontier theory. At the same time, five evaluation methods are sorted out: (i) Solow residual method; (ii) growth accounting method; (iii) SFA; (iv) DEA method; and (v) data envelopment analysis method [21–24]. In view of the current situation, when scholars evaluate the efficiency of the construction industry, most of them are based on the theory of production frontier.

Based on this theory, the above five methods can be classified into two categories according to whether parameters are introduced or not. (i) One is parameter analysis method, and (ii) the other is nonparameter analysis method. Compared with parameter analysis method, the nonparameteric method does not need to build specific functions in the process of form. However, we rely on the observation method to obtain the data of production points. Combined with the production standards, there will be production points in front of the envelope, which is not conducive to the economic analysis of the system. In the field of efficiency evaluation of the construction industry, the difference between evaluation theory and evaluation method is whether correlation analysis can be carried out based on quantitative perspective or not [22]. Considering that evaluation theory does not support quantitative analysis, this paper chooses the latter one, that is, to carry out corresponding evaluation work through the evaluation method. Due to the influence of length, this paper only introduces some representative evaluation methods and makes a horizontal comparison, from the most suitable method for building efficiency evaluation work.

### 3.3. The Data Envelope Analysis (DEA) Method

The data envelope analysis (DEA) was first put forward by Charles et al. in 1978. It is an analysis method that comprehensively uses the knowledge of many disciplines including operations research, management science, and mathematical economics. The DEA method is built on the basis of the concept of “relative efficiency,” which is a systematic analysis method that can deal with multi-input and multi-output index system and evaluate the relative effectiveness. It shows many advantages in solving multi-objective decision-making problems. Its essence is based on a set of data related to multiple inputs and outputs and depends on the corresponding mathematical programming model to greatly improve the production efficiency. The DEA says this is a combination of input and output of the effective group, assignment to 1, if you are out of the efficiency of production frontier, it is classified as inefficiency, and at the same time, a specific efficiency indicator is determined in the interval from 0 to 1.

Taking decision unit (DMU) as the object, it is assumed that its corresponding input vector in a certain production activity can be represented as \( x = (x_1, x_2, \ldots, x_m)^T \), and its output vector can be represented as \( y = (y_1, y_2, \ldots, y_m)^T \).

It is, then, possible to describe the total production activities involved in the DMU by \((x, y)\).
Now there are \( n \) DMUs \((1 \leq j \leq n)\), \( m \) input indicators, and \( S \) output indicators corresponding to each DMU \( U_j \). The vectors representing the input and output are as follows [14]:

\[
\begin{align*}
  x_j &= (x_{1j}, x_{2j}, \ldots, x_{mj})^T > 0, \; j = 1, 2, \ldots, n, \\
  y_j &= (y_{1j}, y_{2j}, \ldots, y_{mj})^T > 0, \; j = 1, 2, \ldots, n.
\end{align*}
\] (1)

Furthermore, the value of \( x_{ij} \) and \( y_{ij} \) is computed as follows [20]:

\[
x_{ij} > 0, \; y_{ij} > 0, \; i = 1, 2, \ldots, m; \; r = 1, 2, \ldots, s.
\] (2)

At the same time, if \( v_i \) is the weight of the \( i \)th input indicator and \( u_r \) is the weight of the \( r \) output indicator, then each decision element DMU \( j \) corresponds to an efficiency evaluation index that is characterized by the following equations:

\[
\begin{align*}
  h_j &= \frac{u^T y_j}{v^T x_j} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}, \; j = 1, 2, \ldots, n, \\
  v &= (v_1, v_2, \ldots, v_m)^T, \; u = (u_1, u_2, \ldots, u_s)^T.
\end{align*}
\] (3)

The weight vector values, corresponding to input vector and the output vector, are not specified in advance, but are determined effectively based on rules in the analysis link. According to Charnes–Cooper transformation, let us assume

\[
t = \frac{1}{v^T x_o}, \; \omega = tv, \mu = tu.
\] (4)

The above equation is processed with line variation, and the following linear programming is obtained:

\[
\begin{align*}
  \max h_{j0} &= \mu^T y_0 \\
  \text{s.t.} \; \omega^T x_j \mu^T y_j &\geq 0, \; j = 1, 2, \ldots, n \\
  \omega^T x_0 &= 1 \\
  \omega \geq 0, \mu &\geq 0
\end{align*}
\] (5)

The dual programming corresponding to this linear programming can be expressed as

\[
\begin{align*}
  \min &\sum_{j=1}^{n} \lambda_j y_j \\
  \text{s.t.} \; \lambda_j x_j &\leq \theta x_0 \\
  \sum_{j=1}^{n} \lambda_j y_j &\geq y_0 \\
  \lambda_j &\geq 0, \; j = 1, 2, \ldots, n
\end{align*}
\] (6)

The major advantages of the DEA method are as follows:

(1) The production performance corresponding to the decision-making units with multiple inputs and outputs can be effectively evaluated. In the process of applying DEA method, there is no need to specify the form of production function corresponding to input-output. Therefore, it can effectively evaluate the efficiency of decision-making units with complex production relations and many input-output indicators.

(2) It is endowed with the characteristic of unit invariance. Specifically, in the evaluation process of the DMU results, it can get rid of the influence of the actual units used for input-output data. When input-output data use the same unit, no matter which unit of input-output data changes, the final efficiency result will not be affected. It can be processed simultaneously with both proportional data and nonproportional data. Specifically, in the input-output data, proportional data or nonproportional data can be used, as long as these data can present the key indicators involved in the input side or the output side of the decision-maker.

(3) In the DEA model, the weight is obtained by processing relevant data through mathematical programming, and there is no need to set the weight of input and output in advance. Therefore, the adverse influence brought by subjective factors can be effectively avoided. In contrast, such ex ante enactment weighting methods represented by expert assessment can hardly avoid the influence of human-centered factors.

(4) The DEA approach can put the target value and actual value together for comparative analysis. In addition, it can also support efficiency analysis, etc. It can deeply understand and comprehensively grasp the actual utilization of resources in decision-making units and provide beneficial reference for managers to make more scientific management decisions.

Therefore, it can be concluded that the DEA method is a very effective approach to evaluate the regional economic efficiency.

4. Construction of the Evaluation Model

4.1. Basic Model of the DEA Method. The basic models of the DEA method mainly include different models, i.e., (i) CRS-CCR model and (ii) VRS-BCC model. Among them, the CRS model assumes constant returns to scale (CRS for short), but in reality, not every research object is produced under fixed returns to scale. Therefore, variable returns to scale (VRS for short) must be considered and should be taken into account. The VRS model meets the analytical needs of measuring relative efficiency values under different states of returns to scale [23].

The difference between the VRS model and the CRS model is that the assumption is changed from fixed return to scale to variable return to scale. In VRS model, the comprehensive efficiency index is decomposed into the product of pure technical efficiency and scale efficiency, so that we can know how much of the comprehensive technical inefficiency of the city comes from pure technical inefficiency.
and how much comes from scale inefficiency. The comprehensive efficiency index in the VRS model reflects the allocation of urban elements and its governance level, as well as the efficiency problems caused by scale aggregation. Pure technical efficiency index only reflects the allocation and utilization level of urban factor resources, which is mainly caused by the change of management system. Scale efficiency index represents the efficiency of urban scale agglomeration, which is mainly caused by the productivity. In order to solve the comprehensive efficiency, scale efficiency, and pure technical efficiency of the China’s construction industry, the VRS model is selected.

4.2. The DEA-VRS Model. The DEA-VRS model was developed on the basis of CRS model by Banker and other scholars aiming at the problem that CRS model could not be used to evaluate the efficiency of evaluation units with variable returns to scale and could not specifically study the shortcomings of pure technical efficiency and scale efficiency [24]. The hypothesis given by this model is “variable returns to scale,” which can specifically study the comprehensive efficiency, pure technical efficiency, and scale efficiency of construction industry. Under normal conditions, the corresponding linear programming form of this model can be expressed as

\[
\begin{align*}
\min \left[ \theta - \varepsilon \left( \sum_{j=1}^{n} s^-_j + \sum_{j=1}^{s} s^+_j \right) \right] &= V(d) \\
\text{s.t.} \sum \lambda_i x_{ij} + s^-_i &= \theta_{\varepsilon i}, (i = 1, 2, \ldots, n) \\
\sum \lambda_i y_{ij} - s^+_i &= \theta_{\varepsilon j}, (j = 1, 2, \ldots, n) \\
\sum \lambda_i &= 1, \lambda \geq 0 \\
s^- \geq 0, s^+ \geq 0
\end{align*}
\]

(7)

In the above formula, \(x_{ij}\) refers to the specific quantity of the \(i^{th}\) input indicator actually required by the decision-making unit at the \(j^{th}\) position. Similarly, \(y_{ij}\) refers to the specific quantity of the RTH output indicator actually required by the decision-making unit at the \(j^{th}\) position, and \(\alpha_{ij}\) refers to the combinatorial ratio in the case that the DMU at the \(j^{th}\) position uses linear combination to form the so-called efficient DMU. Moreover, \(\varepsilon\) refers to the non-Archimedean infinitesimal, \(S^-\) and \(S^+\) refer to the relaxation variable, and \(\theta\) refers to the efficiency value corresponding to the DMU at the \(j^{th}\) position. Through solving and calculating the linear programming problem, as described in the above (7) for \(n\) times, the efficiency values corresponding to each decision-making unit can be finally obtained.

4.2.1. Convergence Test Model. Based on the calculation results of the construction efficiency, the convergence test model is used to calculate the coefficient of variation (CV) of efficiency to test the convergence of construction efficiency. The variation trend of efficiency spatial difference is measured by the variation coefficient of efficiency in the construction industry. The coefficient of variation can be expressed in various forms, including mean variation, range variation, and standard deviation variation. In this paper, standard deviation variation coefficient is used to test the convergence of construction efficiency. This can be computed using formula (8).

\[
CV = \frac{1}{\text{TFP}} \sqrt{\frac{1}{n} \sum_{i=1}^{n} [\text{TFP}_i - \text{TFP}]^2},
\]

(8)

where \(t\) represents the variation coefficient value, \(i\) represents the number of regions, \(\text{TFP}_i\) represents the construction efficiency value of the \(i^{th}\) region, and \(CV\) represents the average construction efficiency value, respectively. The coefficient of variation reflects the absolute difference degree of cumulative efficiency of construction industry. The smaller the number of variation lines is, the greater the absolute difference of efficiency of construction industry among provinces and regions.

4.2.2. Convergence Test Model. In order to further analyze the convergence characteristics of the construction industry in east and west China, this paper conducts convergence test on construction efficiency on the basis of convergence test. The absolute convergence model is used to investigate whether the provinces and regions with lower efficiency of the construction industry catch up with the provinces and regions with higher efficiency. The conditional convergence model is used to investigate whether the efficiency of construction industry is approaching its own steady state. The equation of absolute convergence test model is

\[
\frac{\ln \text{TFP}_{it} - \ln \text{TFP}_{i0}}{T} = \alpha + \beta \ln \text{TFP}_{i0} + \epsilon_{it}.
\]

(9)

In the above formula, \(\text{TFP}_i\) and \(\ln \text{TFP}_i\) represent the comprehensive efficiency of construction industry at the beginning of the period and the \(i^{th}\) province and region in the reporting period, respectively. Moreover, \(T\) is the time span, \(\alpha\) is the parameter to be estimated, and \(\epsilon\) is the random error term with absolute convergence.

4.3. Constructing an Index System for Input-Output

4.3.1. Basic Principles for Selecting an Input-Output

In the quantitative measurement and analysis of the efficiency of construction industry, by using data envelopment analysis method, scientific and reasonable input and output indicators should be selected to build a comprehensive and effective index system. This will ensure the scientific and objective of the final measurement results. As a labor-intensive and resource-intensive industry, the production process of the construction industry is relatively complex. In the production process, a large amount of labor and social resources are often needed, and there are many types of output. There is a big gap between the actual input and output of the construction industry and other industries. Therefore, the following principles should be followed when selecting input and output indicators:
(1) Purpose: this paper constructed the index system of the ultimate goal that is to be on the efficiency of domestic construction industry. There exists the space difference, for precise and objective evaluation. Then, from the time series and the spatial distribution of multiple dimension space differences, the efficiency of construction is analyzed. In addition, we explore the changing trend and causes of the differences, and then provide reasonable measures for its suggestions. Therefore, indicators that can affect the efficiency of the construction industry need to be selected, and then comprehensive consideration of relevant input and output indicators for further screening.

(2) Evaluation: the scientific analysis and evaluation of the relevant data are based on the whole index system, which can accurately and objectively reflect the efficiency differences in the domestic construction industry in space. In order to ensure that the theory has scientific characteristics, it is necessary to comprehensively consider the actual situation to set up the relevant index system. Both areas related to construction information should be collected, on the basis of this built scientific and reasonable mathematical model, and to the construction industry in the area of the index system of building complex part of the real, objective evaluation index to reflect the practical efficiency in the field of construction. When using the theoretical average value, it cannot comprehensively and objectively reflect the efficiency of the construction industry in the region. It needs to be replaced.

(3) Comprehensiveness: in view of the changeable environment of the industry and the complexity of the industry itself, there will be many factors hindering the development of the construction industry. If any one of these factors is ignored in the measurement of efficiency presented in the construction industry, the final result will be significantly biased. Therefore, when evaluating the efficiency of the industry, the measurement factors must be comprehensive, so key indicators must be integrated into the index system in the analysis.

(4) Representativeness: when the evaluation method of DEA is used, the number of indicators will be limited, so it is necessary to select highly representative indicators. For example, if the correlation among multiple indicators shows linear characteristics, only one indicator should be retained, and this indicator should cover the characteristics of other indicators. Try to make the selected indicators reflect relevant information without overlapping information, to maximize the reduction of relevant indicators to objectively and accurately reflect the efficiency information related to the industry.

(5) Authenticity: in order to ensure the accuracy of efficiency measurement, it is necessary to ensure that all data in the indicator system are true and objective. Therefore, this paper selects the corresponding data from “China Statistical Yearbook” and “Construction Industry Statistical Yearbook” to construct the index system, so as to ensure the authenticity of the evaluation conclusion to the greatest extent.

(6) Index system: the practical index system has two functions— one is the basis for calculating the efficiency of construction industry, second, managers have reference value when making decisions. Therefore, in the acquisition of data in the index system, it is necessary to ensure that the data collection process has the characteristics of convenience and follow-up consistency [25].

5. Experimental Analysis

The efficiency of the construction industry has been quantitatively measured and analyzed from the three dimensions of the whole country, (i) east and (ii) west, as well as (iii) provinces and cities. Then, on the basis of calculation results, using the clustering analysis method, convergence and nonconvergence characteristics from the space distribution and variation are considered, respectively. The convergence of three directions of further analysis on the spatial distribution of the efficiency of construction industry, in China, is analyzed. Moreover, in the whole observation period characteristics, trends, and the efficiency of the construction, space difference in the whole sequence space exists in the process of evolution convergence.

In the efficiency calculation process, DEAP2.1 software was used in this paper to automatically calculate and analyze the efficiency. Before running the software, parameters of the software model need to be set. The VRS model is selected to classify the initial index data in the order of output index data first and input index data last. Next, the software converts it to DTA format and saves it to the specified program folder. The following will be based on the efficiency value of the calculated time and space comparative analysis. In addition, the efficiency level of China’s construction industry spatial difference and change trend, for the future regional balanced development of the construction industry, can improve the efficiency of China’s construction industry in order to provide a reference.

5.1. Analysis of Efficiency Time Series Difference in China’s Construction Industry. From a national perspective, although the average efficiency level of China’s construction industry is not fully effective, however it shows a steady upward trend. The calculated results are arranged in chronological order, as shown in Table 2.

As can be seen from Table 2 and Figure 1, the comprehensive efficiency of China’s construction industry increased from 0.733 in 2008 to 0.846 in 2018, with an average annual growth rate of approximately 1.31%, showing an overall upward trend. Among them, the pure technical efficiency increased from 0.751 in 2008 to 0.871 in 2018, with an average annual growth rate of 1.36%. The overall trend was also on the rise. Moreover, the scale efficiency increased from 0.976 in
Table 2: 2008–2018 efficiency of the construction industry in China.

<table>
<thead>
<tr>
<th>Year</th>
<th>The comprehensive efficiency</th>
<th>Pure technical efficiency</th>
<th>The scale efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>0.733</td>
<td>0.751</td>
<td>0.976</td>
</tr>
<tr>
<td>2009</td>
<td>0.77</td>
<td>0.784</td>
<td>0.982</td>
</tr>
<tr>
<td>2010</td>
<td>0.816</td>
<td>0.832</td>
<td>0.981</td>
</tr>
<tr>
<td>2011</td>
<td>0.837</td>
<td>0.851</td>
<td>0.984</td>
</tr>
<tr>
<td>2012</td>
<td>0.846</td>
<td>0.867</td>
<td>0.975</td>
</tr>
<tr>
<td>2013</td>
<td>0.884</td>
<td>0.903</td>
<td>0.98</td>
</tr>
<tr>
<td>2014</td>
<td>0.885</td>
<td>0.899</td>
<td>0.984</td>
</tr>
<tr>
<td>2015</td>
<td>0.812</td>
<td>0.84</td>
<td>0.966</td>
</tr>
<tr>
<td>2016</td>
<td>0.827</td>
<td>0.853</td>
<td>0.969</td>
</tr>
<tr>
<td>2017</td>
<td>0.817</td>
<td>0.84</td>
<td>0.972</td>
</tr>
<tr>
<td>2018</td>
<td>0.846</td>
<td>0.871</td>
<td>0.972</td>
</tr>
<tr>
<td>Mean</td>
<td>0.825</td>
<td>0.845</td>
<td>0.977</td>
</tr>
</tbody>
</table>

Figure 1: Variation trend of the efficiency of the construction industry in China.

Figure 2: Variation trend of construction efficiency in east China from 2008 to 2018.
2008 to 0.972 in 2018, with an average annual growth rate of −0.04%, showing an overall downward trend. In absolute value, scale efficiency obviously exceeds pure technical efficiency, suggesting that the biggest reason for the low level of efficiency in China’s construction industry is relatively low technological progress and poor internal management, rather than insufficient investment scale in the construction industry.

At the same time, although the pure technical efficiency of the construction industry is relatively low, it has improved every year and is developing in a good direction. In the future, construction enterprises should focus on improving the technical efficiency of construction enterprises and improve the pure technical efficiency of construction enterprises through the introduction of foreign advanced technology and independent research and innovation.

5.2. Analysis of Construction Efficiency and Characteristics of Eastern China. Although the efficiency of construction industry in eastern China is not fully effective, it shows a steady upward trend. The calculated results are shown in Table 1 and Figure 2.

As can be seen from Table 1 and Figure 2, the comprehensive efficiency of the construction industry in eastern China increased from 0.794 in 2008 to 0.904 in 2018, with an average annual growth rate of approximately 1.18%, showing an overall upward trend. It showed a steady upward trend from 2008 to 2013 and began to decline in 2014, followed by significant and nontrivial fluctuations. In this decade, only 2014, 2015, and 2017 saw negative growth, with growth rates of −1.1%, −6.5%, and −0.13%, respectively. Moreover, the year 2015 saw the fastest decline in the comprehensive efficiency of the construction industry. All other years were positive, with a maximum increase of 4.43% in 2009.

6. Conclusions and Future Work

Based on the proposed evaluation model and index system, this paper analyzes the efficiency of the construction industry in China by time series difference analysis, spatial difference characteristic analysis, cluster analysis, and convergence analysis. Based on the longitudinal comparative analysis of the time series from 2008 to 2018 and the horizontal comparative analysis of China’s major provinces and regions in space, the changing trend and causes of the spatial difference in the efficiency of construction industry in China are obtained. Based on the analysis results, the paper aims at adjusting the industrial structure, standardizing the construction industry market, steadily promoting the urbanization process, promoting the balanced regional development of the construction industry, improving the level of science and technology, and improving the technical content of the construction industry at the three levels of the national, eastern, and central and western regions. Suggestions are put forward to improve efficiency of the construction industry and promote regional balanced development of the construction industry from four aspects of establishing information platform and improving modernization level of the construction industry.

In the future, we should focus on improving the technical efficiency of the construction enterprises and improve the pure technical efficiency of the construction enterprises through the introduction of foreign advanced technology and independent research and innovation. Moreover, research is required in this direction. Similarly, other performance metrics should be taken into account to study the generalization of the proposed method, its outcomes, and its applicability in a real-world scenario.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References


