Study on the operational efficiency of prefabricated building industry bases in Western China based on the DEA model

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Abstract

Prefabricated building industry bases emerged at exactly the right moment, and therefore coincided with the transformation and upgrade of the construction industry and the rapid development of urbanization, but the analysis of the process through which prefabricated buildings develop often neglects the actual operating efficiency of prefabricated building industry bases. This is due to differences between the western region and other regions that relate to, *inter alia*, policy, technology level, standard specification, and market demand. The study of the operational efficiency of prefabricated building industry bases in the western region is therefore of great significance. This paper uses a literature review and expert correction to establish an input–output index system. It also conducts field research in different regions and uses the Data Envelopment Analysis (DEA) research method to analyze overall differences between prefabricated building industry bases in Western China and other regions. It also draws on macro and micro perspectives to assess problems that exist in their own operations. In conclusion, it provides four targeted suggestions that operate from within government and base investor perspectives.

Keywords Prefabricated building · Industry base · Operating efficiency · DEA model · Western China

Introduction

With the continuous acceleration of urbanization, China's economy has achieved rapid development, and the construction industry has increasingly become an important engine driving national economic growth (Guo et al. 2019). The huge construction market puts forward new requirements in terms of the production mode of the construction industry. Using the

traditional extensive production mode, which is characterized by high consumption and high pollution, it is difficult to meet the current demand for economic development. Moreover, prefabricated buildings can achieve the perfect combination of energy conservation and environmental protection using green construction (Shi and Wang 2020). Indeed, during the COVID-19 outbreak, Wuhan Huoshenshan and Leishenshan Hospital successively sprang up, which made the market fully recognize the efficiency and advantages of prefabricated buildings. In the context of the country's vigorous promotion of new infrastructures, such as 5G, artificial intelligence, industrial Internet, smart cities, education, and medical care, prefabricated building most closely represents the new infrastructure direction (Feng 2020).

In 2016, the General Office of the State Council issued the Guiding Opinions on Vigorously Developing prefabricated buildings, promoting prefabricated buildings at the national level. In recent years, relevant policies on prefabricated buildings have been constantly introduced in various places, and the proportion of prefabricated buildings in new buildings has been constantly increasing (Qin 2020). At present, the construction of assembly construction industry bases is in full swing. Its development modes mainly include the resource

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integration mode led by real estate development enterprises, the development mode led by general construction contracts, the EPC whole industry chain development mode, etc. According to the “China Prefabricated Construction Development Report,” released by the Ministry of Housing and Urban-Rural Development in 2017, there are about 611 prefabricated construction production enterprises nationwide, with a total of 1786 production lines (Wen 2017).

However, the development of prefabricated buildings in China is still in the initial stage, and the prefabricated market is not mature yet (Xie 2014). Prefabricated buildings in most regions mainly rely on policy incentives, and the implementation rate of some policies is not high; existing technical standards show a relative lag and it is difficult to match the development of prefabricated buildings; the number of newly built prefabrication factories is also large and the scales are different; most factories have unreasonable planning and design, and actual production capacity is far from designed capacity. Most factories also have large hardware investments, high operating costs, low management experience and rely on low-price competition to an excessive extent, and they fail to determine the production scale of enterprises based on the market demand and development trends of the components, resulting in an overcapacity. In some regions, factories are in a state of production, resulting in loss-making operations or even closure (Ge et al. 2020; Qi and Wang 2020). Therefore, it is extremely important to conduct an in-depth study on the operation efficiency of prefabricated building industry bases.

The number of newly built prefabricated factories is large and the scales are different. Most of the factories have unreasonable planning and design, and the actual production capacity is far from the designed capacity. Most factories have large hardware investments, high operating costs, lack of management experience, and excessive reliance Low price competition to obtain orders,

Orders did not determine the production scale of the company based on the market demand and development trend of the components, resulting in overcapacity, and factories in certain areas were in a state of waiting for production, resulting in loss-making operations or even closure

Based on this, this article explores:

- (1) The differences in terms of the operating efficiency of prefabricated building industrial bases in China;
- (2) The specific development problems pertaining to the operation efficiency of prefabricated building industrial bases in Western China; and
- (3) Countermeasures and suggestions regarding the development of prefabricated building industrial bases in Western China.

The research framework of the full text is shown in Fig. 1.

Literature review

At present, foreign research on prefabricated building pay more attention to technological innovation, market development strategies, etc., while domestic scholars study innovation in prefabricated building technology, organization management, development trends, influencing factors, and countermeasures (Ding 2019; Jiao 2019; Alweshah et al. 2020; Haoxiang et al. 2018; Huang et al. 2018).

With regard to technological innovation, Pedro C.P. Silva et al. (2013) proposed a new prefabricated retrofit module solution that demonstrates the implementation of the retrofit module in the integrated transformation method, with the ultimate goal of obtaining a building solution with the lowest possible energy consumption and greenhouse gas emissions (Silva et al. 2013). Pašek (2016) selected a group of buildings that had previously been transformed and whose energy consumption and heating consumption could be reduced, focusing on analyzing and assessing the economic effectiveness of measures taken to reduce the energy demand of prefabricated housing (Pašek and Tvrzníková 2016). Lu (2012) proposed that the material recycling potential of houses with a prefabricated steel structure is huge, which is reflected in their energy savings of 81% and material savings of 51%. This form of construction has the potential to make a significant contribution to improving the environmental sustainability of the construction industry (Aye et al. 2012). Junjie Li et al. (2016) applied BIM technology to the production mode operation system of prefabricated buildings and built a BIM-based logistics management system, construction coordination system, and facility management system, which realized the controllability of the cost of prefabricated components and the simulatability of the production process (Li and Yang 2016). With regard to market development, Yongsheng Jiang extracted 16 indicators from a literature review and expert interviews to assess sustainability in the construction phase, and the results show that, compared with conventional buildings, prefabricated buildings are more obviously sustainable during the construction phase (Jiang et al. 2019a). Sun L Z (2012) analyzed the low-carbon characteristics of products of construction industrialization and market failures caused by external factors, introducing the market mechanism of carbon trading to allow the supply and demand of products of construction industrialization to come close to or reach the Pareto-optimal state (Sun and Wu 2012). El-Abidi (2015) shows that the adaptability of prefabricated buildings depends primarily on factors, such as labor shortages, labor costs, housing demand, building efficiency, weather, reduced waste, and energy consumption (El-Abidi and Ghazali 2015). Z L Guo et al. (2017) combined a rough set theory to redefine the factors that affect the risks associated with prefabricated housing (Guo et al. 2017). Jiang (2019) selected four indicators, namely, the number of

Fig. 1 Research framework

prefabricated component production enterprises, prefabricated building area, prefabricated building market size, and expected prefabricated building area ratio, to evaluate the effectiveness of a prefabricated building incentive policy (Jiang et al. 2019b). Pan (2020) combined the results of a questionnaire survey and those of related literature identified 10 influencing factors that hindered the implementation of prefabricated buildings in China, and used the ISM method to construct a multi-level hierarchical structure model of influencing factors. This research shows that insufficient research investment and insufficient government propaganda are the most fundamental influencing factors (Haize et al. 2019). In terms of cost control, Chen et al. (2019) used the information technology system in the application of prefabricated components to study the interrelation and coupling between the three phases of prefabricated components and, finally, to analyze the factor collection affecting the construction cost of prefabricated buildings (Chen et al. 2019). Xiong et al. (2019) used the Arena software to simulate the total time and error in using RFID technology and not using RFID technology and compared and analyzed the benefits of investing in RFID technology (Xiong et al. 2019). From the perspective of prefabricated building components and the full life cycle of buildings, Wu (2019) compared the incremental cost and benefit of prefabricated building and cast-in-place building and obtained a cost-effective prefabricated rate and component combination scheme (Wu 2019). Based on the product externality theory, Li (2016) analyzed the reasons for the price compensation of prefabricated buildings, determined the principle of price compensation, explored compensation standards, designed a price compensation mechanism, and made recommendations to accelerate the development of prefabrication

buildings, making it rapid and efficient (Li and Zhang 2016).

Research on prefabricated building industry bases mainly has focused on the selection of a production facility arrangement, the production process of prefabricated components, the management of the order production mode, quality control, and the application of information technology (Li 2019; Dai 2019). According to the site workshop layout of the production lines of prefabricated components and functional area classification, Yang (2015) divided the production line control system into 5 subsystems and used a three-layer network structure to achieve the management and control of the production process of prefabricated concrete components (Lu 2015). In a study on the selection of forms of production facility arrangements, Zhu (2013) pointed out that production line layouts should be studied in various mixed production lines of different lengths, because this will allow the logistics path to be optimized and the production cost to be reduced (Zhu 2013). Using social, economic, natural, cost, and industrial perspectives, Liu (2019) established an index system of industrial base locations, calculated the influencing degree, influenced degree, center degree, and cause degree using the DEMATEL method, and conducted an empirical analysis, indicating the main factors that must be considered in relation to industrial base location and proposing countermeasures and suggestions regarding the location of prefabricated construction industry bases (Liu and Liu 2019).

An analysis of the existing research results shows that scholars at home and abroad pay a significant amount of attention to prefabricated building. The existing research has the following characteristics: first, the research on prefabricated building is extensive, but the research on

prefabricated industry bases is not; second, because domestic prefabricated buildings are in the early stage of industrial development, there is a lack of collection and quantitative analysis of relevant data, and the related research is mostly qualitative; third, there is a lack of research on the actual operational efficiency of the prefabricated building industry bases in China. Other oversights include differences between the western region and other regions; the question of how the input and output of the industrial base in the western region can be made efficient; and ways to improve the construction of the follow-up base.

For these reasons, this paper uses the data envelopment analysis (DEA) method to study the input and output of prefabricated building industry bases, analyzes the differences between different regions of China in terms of the development of prefabricated building bases, and then analyzes the existing problems in the western region, providing suggestions regarding the construction of bases in the western region. This paper therefore has a strong theoretical and practical significance.

Research methods and index system

Research methods

The common evaluation methods used in efficiency analysis are hierarchical analysis, main component analysis, fuzzy evaluation, game theory, and data envelopment analysis (DEA) (Gong et al. 2020; Cheng 2019; Ding et al. 2020). The analytic hierarchy process and fuzzy evaluation are more statutory and subjective, and game theory is mostly used to analyze the game relationship between multiple subjects. They are not suited to research into the operating efficiency of prefabricated building industry bases. This study analyzes the operational efficiency of prefabricated building industry bases, because it involves multiple input and output indexes, and it is difficult to construct a production function and efficiency function with a clear and unified form, making it extremely difficult to measure the operational efficiency of prefabricated building industry bases effectively (Gao et al. 2019). DEA, as an efficiency evaluation method, extends the concept of the engineering efficiency of a single input and single output to the efficiency evaluation of a similar decision-making unit (DMU) with multiple inputs and multiple outputs. This enriches the theory relating to production function and its application technology in micro-economies. Moreover, it does not require the dimensional processing of data before the DEA method is applied in the model (Sun 2020; Zhao n.d.). Using the DEA effectiveness evaluation method, we can not only comprehensively evaluate the relative efficiency of each decision unit but also obtain a lot of

management information that has significant economic implications (Bansal et al. 2021; Yousefi et al. 2021). It is used to guide the improvement and correction of the input and output values of each decision unit (Chen et al. 2020). Accordingly, the DEA method is used to evaluate the operational efficiency of prefabricated building industry bases.

Since the traditional DEA CCR model decision-making unit is DEA effective, it must be both “technically effective” and “scale effective” (Ma and Ma 2015). Therefore, it is difficult to distinguish between scale efficiency and technical efficiency when the DEA is invalid in the CCR model, so the BCC model is used for evaluation. The expression is as follows:

$$BC^2 = \begin{cases} \min \left[\theta - \varepsilon \left(e^T s^- + \hat{e}^T s^+ \right) \right] = h^{BC^2} \\ \sum_{j=1}^n x_j \lambda_j + s^- \leq x_0 \\ \sum_{j=1}^n y_j \lambda_j - s^+ \geq \theta y_0 \\ \sum_{j=1}^n \lambda_j = 1 \\ \lambda_j \geq 0, j = 1, \dots, n \\ s^+ \geq 0, s^- \geq 0 \end{cases} \quad (1)$$

where $\varepsilon > 0$ is non-Archimedes infinitesimal:

$$\begin{aligned} e &= (1, 1, \dots, 1)^T \in E^m, \\ \hat{e} &= (1, 1, \dots, 1)^T \in E^s. \end{aligned} \quad (2)$$

The production possibility set is:

$$T_{BC^2} = \left\{ (x, y) \left| \begin{array}{l} \sum_{j=1}^n x_j \lambda_j \leq x, \sum_{j=1}^n y_j \lambda_j \geq y \geq 0 \\ \sum_{j=1}^n \lambda_j = 1, \lambda_j \geq 0, j = 1, \dots, n \end{array} \right. \right\} \quad (3)$$

where the comprehensive efficiency value is equal to the product of the pure technical efficiency value and scale efficiency.

Selection of evaluation indicators and investigation

DEA index selection of prefabricated building industry bases should be selected in order to conform to the principles of directionality, science, diversity, measurability, simplification, and maneuverability. Based on the literature review and practice, this paper comprehensively summarizes the list of input and output indicators and then determines the index system of DEA analysis by interviewing experts and researchers of prefabricated building industry bases.

Table 1 Input index composition of prefabricated building industry bases

Indicator composition	Composition
Direct production costs	<p>Raw material spending Including the cement, stone, sand, water, rebar, admixtures, finish materials, insulation materials, doors, windows, and other materials. The material cost should include the freight to the factory and consider the material wastage.</p> <p>Auxiliary material costs Including the release agent, protective layer pad, retarder, product identification agent repair material, and other costs. The auxiliary material fee should also include the freight to the factory and consider the material wastage.</p> <p>Connection fee Including the cost of the grout sleeve, bellows, sandwich insulation board tensile parts, and other connectors, in addition to the freight to the factory.</p> <p>Built-in fitting fee Including the cost of de-molding the built-in fitting, flipping the built-in fitting, hoisting the built-in fitting, supporting the built-in fitting, and other built-in fittings, in addition to the freight to the factory.</p> <p>Labor costs Including the labor costs for each production link, including the wages, provident fund, labor insurance, trade union funds, and other welfare expenses.</p> <p>Mold cost allocation The mold fee refers to the total cost of purchasing or making the mold, and the mold fee is apportioned to each component according to the turnover times.</p> <p>Manufacturing costs Including the water, electricity, steam and other energy costs, machinery and equipment sharing, and low-value consumable goods cost allocation.</p>
Indirect production costs	Including the management and laboratory personnel wages, labor insurance, provident fund, trade union funds, and other welfare expense allocation, including the purchase of land formed by the amortization of intangible assets, plant and equipment and other fixed assets depreciation, the fixed or mobile mold, special lifting and support, repair costs, heating costs, product protection and packaging costs, and other expense allocation.
Freight charges	Including transportation costs incurred for the transportation of prefabricated components from the base to the construction site.
Administrative expenses	Including the company's administrative and technical qualities, wages for financial and logistics service personnel, labor insurance, provident fund, trade union funds, other welfare expenses, travel expenses, entertainment expenses, office expenses, transportation expenses, communications and office facilities, equipment depreciation, maintenance costs, research and development expenses, financial expenses, external inspection fees, and other allocations.
Taxes	Including the land use tax, property tax allocation and prefabricated components of their own value-added tax, urban construction tax, and education fee surcharges, as well as administrative charges.

Input indicators

The input indicators of prefabricated building industry bases mainly include the direct production costs, indirect production costs, freight, management costs, and taxes (Xu 2020), as shown in Table 1.

Output indicators

Drawing on the literature and on the basis of field research, the output index of this paper is considered to have two factors: profit and capacity. It should be noted that the capacity here refers to the actual production capacity of bases, rather than their design capacity. Therefore, there are 5 input indicators and 2 output indicators in this paper, as shown in Table 2.

Table 2 The input and output indicators for prefabricated building industry bases

Indicators	Indicator layer	Unit
Input indicators	Direct production cost (X_1)	Ten thousand yuan
	Indirect production cost (X_2)	Ten thousand yuan
	Freight (X_3)	Ten thousand yuan
	Management fee (X_4)	Ten thousand yuan
	Tax (X_5)	Ten thousand yuan
Output indicators	Profit (Y_1)	Ten thousand yuan
	Capacity (Y_2)	Ten thousand m ³

Data sources

Twenty members were trained, gaining skills relevant to the prefabricated building industry. In order to ensure the authenticity and analytical nature of the data, a questionnaire was designed to fill in the blanks, and the group members regularly attended follow-up sessions at their respective research bases.

As there is a lack of current research literature on the operational efficiency of prefabricated building industry bases, and the relevant data are mainly qualitative analysis, from 2016 until now, our research group has carried out a field investigation on prefabricated building industry bases in many

Fig. 2 Survey area map

provinces and cities in China (as shown in Fig. 2), which is limited in terms of research depth, representing the actual situation of operation efficiency of prefabricated building industry bases in China.

Empirical analysis

Macro analysis of the operational efficiency of prefabricated building industry bases in Western China

In order to explore the overall development status of the prefabricated building industry bases in the western region, this paper analyzes the operational efficiency of prefabricated building industry bases in the eastern region, the southern region, the western region, the northern region, and the central region using the BCC input guidance model in DEA data envelopment analysis (Gao et al. 2019).

As can be seen in Table 3, from 2016 to 2018, the comprehensive efficiency, pure technical efficiency, and scale efficiency of prefabricated building industry bases in the eastern, southern, and northern regions are all 1, and the returns to scale of the central region decreased in 2018. This shows that the prefabricated building industry bases in the east, south, and north all have an effective operational efficiency.

In the returns to scale in the table, “drs” means descending, “-” means invariant, “irs” means ascending

Because the basic model has multiple efficiency values of 1, we cannot further analyze all of the decision-making units.

In order to solve this defect of the model, Anderson and Peterson and others proposed a super-efficiency model, which has a good property; in the non-Archie Mead Infinitesimal Quantity (DEA efficiency value 1) evaluation unit, the model's super-efficiency can be greater than or equal to 1, and in the DEA invalid evaluation unit, its efficiency value is unchanged and then achieves effective sorting (Zhao et al. 2020; Wang et al. 2020). In order to further analyze the differences in the operational efficiency of the prefabricated building industry bases in the western region and other regions, this paper uses the SOLVER Pro5.0 software to calculate the super-efficiency value of each region, as shown in Table 4.

As shown in Table 4, in the eastern, southern, northern, and central regions, the average super-efficiency values are greater than 1. In the western region, the average super-efficiency is less than 1, that is, the operational efficiency of the prefabricated building industry bases in the western region is invalid, and this conclusion is consistent with the results presented in Table 3. In the eastern region, the super-efficiency value is 113.47%, which indicates that even if the prefabricated building industry bases in the eastern region increased their investment by 13.47%, they can still maintain a relatively effective DEA. An additional 4.70% increase in the inputs in the southern region can allow for the maintenance of a relatively effective DEA; an additional 5.23 percent in the northern region can allow for the maintenance of a relatively effective DEA; and a further 0.59 percent increase in the central region can also allow for the maintenance of a relatively effective DEA. Therefore, there are significant

Table 3 Operational efficiency of the prefabricated building industry bases in the five regions from 2016 to 2018

Area	Year	Comprehensive efficiency	Pure technical efficiency	Scale efficiency	Returns to scale
Western region	2018	0.9305	0.9359	0.9942	drs
	2017	0.9290	0.9300	0.9989	drs
	2016	0.9612	0.9673	0.9937	-
Eastern region	2018	1	1	1	-
	2017	1	1	1	-
	2016	1	1	1	-
Southern region	2018	1	1	1	-
	2017	1	1	1	-
	2016	1	1	1	-
Northern region	2018	1	1	1	-
	2017	1	1	1	-
	2016	1	1	1	-
Central region	2018	0.9967	1	0.9967	drs
	2017	1	1	1	-
	2016	1	1	1	-

differences in the efficiency grade between the western region and other regions.

Microanalysis of the operational efficiency of prefabricated building industry bases in Western China

The analysis in the previous section was conducted from the macro perspective. It reflects the lack of operational efficiency of the prefabricated building industry bases in the western region and other regions, but it does not reflect the reasons for the difference and the actual operational status of each prefabricated base in the western region. Therefore, in order to explore the deficiency of the prefabricated building industry bases in the western region and propose reasonable counter-measures on this basis, the microscopic data are analyzed, and the sample data are derived from the field investigation of prefabricated building industry bases in the western region by our research group, as shown in Table 5.

Table 4 Super-efficiency of the prefabricated building industry bases in the five regions from 2016 to 2018

Area	2016	2017	2018	Mean	Sort
Western region	96.12%	92.90%	93.05%	94.02%	5
Eastern region	112.66%	102.58%	125.18%	113.47%	1
Southern region	108.59%	101.31%	104.21%	104.70%	3
Northern region	103.48%	109.75%	102.47%	105.23%	2
Central region	100.61%	101.48%	99.67%	100.59%	4

Comprehensive analysis

The aim of this section is to calculate the operational efficiency of 14 prefabricated building industry bases in the western region (see Table 6). From Table 6, the average comprehensive efficiency is 0.9392, that is, 6.08% of the 14 prefabricated base inputs studied in the western region is wasted or does not contribute to the output, and 10 prefabricated building industry bases have an ineffective operational efficiency (the comprehensive efficiency value is less than 1), so it can be seen that the development of the prefabricated building industry bases in the western region is uneven, and the difference is large.

In the returns to scale in the table, “drs” means descending, “-” means invariant, “irs” means ascending

Non-DEA effective unit analysis

At present, 10 prefabricated building industry bases in the western region, currently under investigation, have a relatively ineffective operational efficiency, and the input and output have not reached a reasonable level. There is an excess input or insufficient output. To ensure that each relatively non-effective unit can reach a relatively effective unit, the paper uses the SOLVER Pro5.0 software to calculate the adjustment value of the input and output, as shown in Fig. 3.

As can be seen from Fig. 3, the input redundancy and insufficient output of the prefabricated building industry base in the western region are reflected in the following findings:

- There is a large number of bases with a redundant input. The input should be strictly controlled. All 10 relatively invalid bases have at least 3 redundant inputs, which

Table 5 Summary of the input and output data for the prefabricated building industry bases in Western China

Base	Input					Output	
	Direct Production cost (X_1)	Indirect production cost (X_2)	Freight (X_3)	Management fee (X_4)	Tax (X_5)	Profit (Y_1)	Capacity (Y_2)
A	3285	468	396	373	686	252	1.8
B	3744	403	320	402	664	243	1.6
C	6919	680	680	663	1231	537	3.4
D	4842	414	460	458	856	400	2.3
E	6588	690	690	630	1185	597	3
F	6386	429	561	515	1096	551	3.3
G	5255	598	520	510	481	957	2.6
H	3955	378	288	369	688	299	1.8
I	2470	240	222	234	440	222	1.2
J	6704	704	672	726	1240	528	3.2
K	3198	320	304	306	574	290	1.6
L	5951	527	540	562	1056	532	2.7
M	6960	578	680	656	1241	666	3.4
N	5372	416	546	538	965	549	2.6

indicates that we cannot continue to blindly increase the resources input of the prefabricated building industry bases in the western region. Each base should adjust its thinking, focus on improving the operational capacity, and then improve the efficiency in the use of the resources invested.

- Except for M and N, there is an indirect production cost input redundancy. According to the current understanding of bases, the prefabricated bases in the western region are mostly newly built. The amortization of intangible assets caused by purchasing land and the depreciation of fixed assets, such as

plant and equipment, accounts for a relatively large proportion of the investment. The planning of the construction of individual bases is separated into several periods. The initial expropriation area of the plant is too large, resulting in an increase of intangible assets amortization and a redundancy of the indirect production costs input.

- Except for E, each base has a management fee input redundancy. Consequently, one can see that there is a surplus of managers in many of the bases in the western region. Some bases do not fully understand the actual situation of the local market, and the investment in office

Table 6 Evaluation results of the operational efficiency of the prefabricated building industry bases in Western China

Base	Comprehensive efficiency	Pure technical efficiency	Scale efficiency	Returns to scale
A	1	1	1	-
B	0.8429	0.8774	0.9607	irs
C	0.9365	1	0.9365	drs
D	0.9110	0.9225	0.9875	irs
E	0.8712	0.8845	0.9850	-
F	1	1	1	-
G	1	1	1	-
H	1	1	1	-
I	0.9424	1	0.9424	irs
J	0.9055	0.9217	0.9824	-
K	0.9616	0.9917	0.9696	irs
L	0.8822	0.8870	0.9946	irs
M	0.9459	1	0.9459	drs
N	0.9498	0.9962	0.9534	irs
Mean	Comprehensive efficiency: 0.9392	Pure technical efficiency: 0.9629	Scale efficiency: 0.9756	

Fig. 3 Adjustment of the input and output index of the invalid prefabricated building industry bases in the western region

and dormitory buildings is also wasteful. In addition, except for C, there is a redundancy in the tax and fee inputs in each base, indicating that the taxes and fees account for a relatively large part of the inputs. When a base is built, it is necessary to proceed pragmatically and avoid an excessive expropriation area. In the meantime, the local government should introduce tax incentives to ease the pressure on enterprises in order to promote the rapid development of prefabricated building in the western region.

Non-DEA effective unit input–output correction

By using the formula, $\hat{x}_{j0} = \theta^0 x_{j0} - s^{-0}$, $\hat{y}_{j0} = y_{j0} + s^{+0}$, the input and output values of each decision unit are revised. The results are shown in Table 7.

Conclusion

Conclusions and recommendations

Through field and literature research, this paper uses the BCC, CCR, and super-efficiency models and the DEA method to evaluate and analyze the operational efficiency of the prefabricated building industry bases in the western region of China from the point of view of the inputs and outputs. The main conclusions are as follows: firstly, at the macro level, whether using the BCC model or super-efficiency model analysis, there is a large gap between the prefabricated building industry bases in the western region and those in other regions, and the operational efficiency is low. Secondly, at the micro-level, ten of the 14 bases studied were relatively ineffective, and there is a large number of base input redundancies, which are reflected in the obvious redundancy

Table 7 Revised results of the input–output for non-DEA effective units

Base	X_1		X_2		X_3		X_4		X_5		Y_1		Y_2	
	Initial	Correction	Initial	Correction	Initial	Correction	Initial	Correction	Initial	Correction	Initial	Correction	Initial	Correction
B	3744	3155.81	403	226.18	320	269.73	402	260.82	664	542.78	243	266.96	1.6	1.6
C	6919	6479.33	680	599.09	680	636.79	663	592.57	1231	1152.78	537	577.89	3.4	3.4
D	4842	4410.84	414	375.05	460	419.04	458	388.97	856	766.09	400	400	2.3	2.3
E	6588	5739.28	690	593.77	690	583.10	630	548.84	1185	957.90	597	597	3	3
I	2470	2327.80	240	172.05	222	209.22	234	193.67	440	383.80	222	222	1.2	1.2
J	6704	6070.36	704	586.54	672	608.48	726	566.61	1240	1102.83	528	528	3.2	3.2
K	3198	3075.14	320	264.26	304	292.32	306	271.95	574	523.84	290	290	1.6	1.6
L	5951	5249.99	527	405.38	540	476.39	562	443.07	1056	840.20	532	532	2.7	2.7
M	6960	6583.17	578	546.71	680	613.69	656	572.21	1241	1068.69	666	666	3.4	3.4
N	5372	5080.52	416	395.12	546	459.14	538	428.66	965	779.47	549	549	2.6	2.6

in the indirect production costs, management fees, and tax inputs.

In order to solve the problems existing in the operation of the prefabricated building industry bases in the western region, the following suggestions are proposed (Xu 2020):

The prefabricated building industry base should uphold the principle of seeking truth from facts and thus should not blindly invest. Too much has been blindly invested in bases in the western region, and the expropriation land area is too large. This significant increase in the amortization of intangible assets resulted in increased costs and an insufficient market competitiveness. In addition, the production process should be determined according to the planning and production needs. At present, there are two main production processes in each base in China. One is the adoption of the production processes of a fixed die table; the other is the use of an assembly line to produce prefabricated plate components, such as laminated plates, and the use of a fixed die table to produce other products at the same time. Because China's prefabricated norms are conservative, and the product standardization is low, the automatic production line is not in accordance with the country's present situation. The design capacity cannot be achieved, and the efficiency is insufficient, so the production process cannot be blindly selected.

The production of prefabricated building industry bases should pursue specialization. The types of prefabricated components put into production in the bases should not be fully covered, and the types of components to be produced should be determined according to regional policies and the state of the enterprise itself. For example, due to the limitation of grade 8 anti-seismic fortification intensity in the Xi'an area, there is almost no demand for vertical prefabricated components in the local market. In this case, the prefabricated base in Xi'an should not take vertical prefabricated components as the mainstream product but should take the superimposed floor slab, prefabricated staircase, prefabricated floating window, and so on, which have large market demand, as the basic products to avoid excessive input and waste.

Production equipment should be selected in accordance with the production process and capacity and product category. The precast component production area and stacking area should be equipped with suitable tonnage lifting equipment. If the lifting range and industrial scale are large, the frequency conversion crane should be selected to effectively improve the production efficiency. In the case of mixer selection, if the production scale is large and the production frequency of different concrete strength grades is high, a feeding system can be introduced to improve mixing capacity and efficiency (this can also avoid inefficiency when replacing concrete of different strength grades).

The production scale of prefabricated building industry bases can be determined according to the market supply and demand situation and the development trend. Before

investing, each base should carry out a market survey on both the supply and demand, not only to investigate the production capacity of prefabricated components in the surrounding area, as well as possible increases in the production capacity, but also to investigate the actual demand situation of the products within the local and reasonable transportation radius, as well as the potential increase in demand.

The governments of the western region should further increase preferential support in terms of taxes and fees. The implementation of tax incentives can effectively reduce the research and development costs of prefabricated construction industry bases, enhance the willingness of enterprises to innovate, reduce the input of enterprises' taxes and fees, and aid in the development of enterprises. At present, other Chinese regions have implemented many preferential policy rules to promote the development of prefabricated buildings that have a strong operability and clear incentives. The governments of the western region should learn from them, formulate some effective preferential policies, encourage enterprises to develop prefabricated buildings, and promote the effective operation of prefabricated building industry bases in the western region.

Weaknesses and future development

This paper uses the DEA Method to study the operating efficiency of China's western prefabricated construction industry bases, and this enables it to determine the input-output index system and establish a scientific theoretical basis for subsequent research. The article's input and output indicators are obtained on the basis of literature collation and practical research, and this may produce the problem of incomplete indicator selection. The article also puts forward more targeted suggestions from government and investor perspectives, but space limitations have meant that it has not been possible to conduct in-depth research into the logical relationship between the prefabricated industrial base and incentive policies. It does, however, point the way in this direction.

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Declarations

Competing interests The authors declare no conflict of interest.

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