Automated Evaluation of the Evacuation Performance for Large Complex Buildings Based on BIM

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Abstract

To evaluate the evacuation performance in building, this paper proposes a method based on BIM. First, an evacuation evaluating index system is established based on BIM. Then, the method obtained data from BIM and used improved BP neural network algorithm to evaluate and check the evacuation performance in building. The case study shows that result can be achieved to evaluate and check the evacuation performance in buildings by BIM and BP neural network. The result can be used to optimize the evacuation performance in building and provide help for the design and operation management.

INTRODUCTION

Evacuation performance is an important field for building fire protection system (Hadjisophocleous and Benichou 1999). The performance influences the building safety management. The building safe limits the building value and the building management. Evacuation performance is the key to improve the building safe and prevent the fatal accidents. In the convention, many methods were implemented in the building design stage. However, in building management, the evacuation performance cannot show reality-time, it affects the evacuation management.

Used BIM technology to analyze building performance is an aspect of its application. Choi et al. (2014) presented a system to check evacuation regulation based on BIM for high-rise and complex buildings. Pauwels et al. (2011) presented a method that checked building regulation for building design and construction. BIM technology can be used to evaluate space structure, check the space safety, evaluate building design etc. (Eastman et al. 2009). Wang et al. (2015) presented a method that uses BIM technology to provide 3D geometry information for evaluating fire safety and optimizing. Isikdag et al. (2008) proposed a method that can transform the geometry information and sematic information from the BIM model to support the site selection and fire response management. Solihin and Eastman (2015) proposed a method of classification of rules and reviewed the development of automated BIM rule checking.

About evaluation methods, Zhang et al. (2013) proposed an approach of fuzzy network analysis to evaluate the emergency evacuation capability of the subway station. Xie et al. (2006) reviewed the assessment methods for building evacuation that included AHP, artificial neural networks (ANN), grey clustering evaluation method etc.

In these researches, they did not connect the evaluation or optimizing based on BIM. Based on this, a platform is designed to evaluate the building evacuation performance based on BIM. This paper is organized as follows: 1) research scope and algorithm, 2) evaluation method description, 3) a case study, 4) discussion and conclusion.

SCOPE AND ALGORITHM

Evaluation indexes. It is the key to select appropriate factors for an evaluation index. For creating the evaluation indexes, we investigated some building maintenance managers, some safety experts, and some building designers and engineers. The evaluation indexes include evacuation door, evacuation passageway, safety exist, evacuation lighting, evacuation sign, warning facility etc., such as show in Table 1.

Quantitative evaluation indexes. According to the regulation, we set the risk ratings. First, each factor is classified the normal operation component and malfunctioning component, and then, calculated the proportion of the normal operation component of each factor in each floor. Each factor is divided three grades: low risk, mid-risk and high risk. Evaluation regulation of risk rating of each factor is shown in Table 1. In the Table 1, some factors are depicted by its quantity. Others are depicted by their character, for example, aisle, smoke prevention facilities, floor location etc. Others, for example, the smoke exhausting facility is depicted by its status and its style.

Evacuation performance and evaluation factors. It is difficult to depict the evacuation performance related to components and facilities. Each influencing factor has the influence of the evacuation performance main, also has secondary. To overcome the influence, the algorithm can deal with nonlinear relation of the factors to achieve automated evaluation.

Evaluation algorithm. It is nonlinear between the evacuation performance and some impact factors. The different factor has different impact for the evacuation performance. For effectively solving the relation between evaluation factors and evacuation performance, we used the BP neural network algorithm to evaluate the evacuation performance based on BIM.

BP neural network algorithm. According to the principle of BP neural network algorithm to establish the evaluation model is shown in Figure 1. For evaluating the building evacuation performance, we defined two hidden layers in the BP neural network algorithm. In the network, X is the input layer, Y^1 and Y^2 are hidden layer, O is output layer. V^1, V^2 and W are weight matrix for the BP neural network.

Table 1.Risk-Division of Each Factor.

Classification	Number	Factor	Normal operation component statistical result		
			Low risk (%)	Mid-risk (%)	High-risk (%)
Evacuation door	A_1	distance to safety exit	>90	90-80	<80
	A_2	door width	>90	90-80	<80
	A_3	number	>90	90-80	<80
	A_4	door opening direction	>90	90-80	<80
Evacuation aisle	A_5	fire-resistant partition wall	>90	90-80	<80
	A_6	width	>90	90-80	<80
	A_7	shape	1	0.5	0.1
Safety exit	A_8	location	>90	90-80	<80
	A_9	number	>95	95-85	<85
	A_{10}	width	>95	95-85	<85
	A_{11}	door opening direction	>90	90-80	<90
Emergency lighting	A_{12}	number	>90	90-80	<80
	A_{13}	location	≥90	90-80	<80
	A_{14}	minimal illumination	>90	90-80	<80
	A_{15}	power on time	>90	90-80	<80
Evacuation indicator sign	A_{16}	number	>95	95-85	<85
	A_{17}	Location	>95	95-85	<85
	A_{18}	Minimal illumination	>90	90-80	<80
	A_{19}	Power on time	>90	90-80	<80
Escape stair	A_{20}	Stair width	>95	95-85	<85
	A_{21}	tread width	>95	95-85	<85
	A_{22}	smoke exhausting facility	1	0.5	0.1
Alarm	A_{23}	location	>90	90-80	<80
	A_{24}	number	>90	90-80	<80
	A_{25}	power rating	>95	95-85	<85
Others	A_{26}	position of floor	<1/3	1/3-2/3	>2/3
	A_{27}	Area of fire compartment	<80	80-95	>95

Improve the BP algorithm. To overcome the drawbacks of the method, in this paper, we used the improve BP neural network by increasing momentum term, learning rate adaptive adjustable strategy and inputting steepness factor. Meanwhile, two hidden layers were used in the BP neural network.

METHOD DESCRIPTION

The evacuation performance was based on the factors that influence the evacuation in buildings. According to geometric information, physical information, logical relation of the building components and facilities, and its operation condition to determine the building evacuation performance.

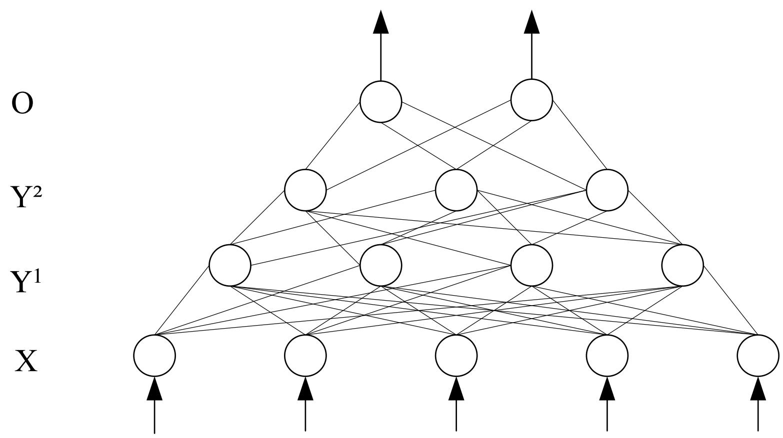


Figure 1.Framework of BP neural network.

Framework of BIM-based automation. The automated evaluation model to evaluate evacuation performance based on BIM, need the data storage function of BIM and the BP neural network algorithm to achieve evaluation. Before the evaluation, we need to transform the building evacuation, the data statistics method and the evaluation method to computer language. Based on these results, the framework of the evaluation of the building evacuation performance is shown in Figure 2. According to the scope and algorithm, we need to develop an evaluation platform of building evacuation performance based on IFC.

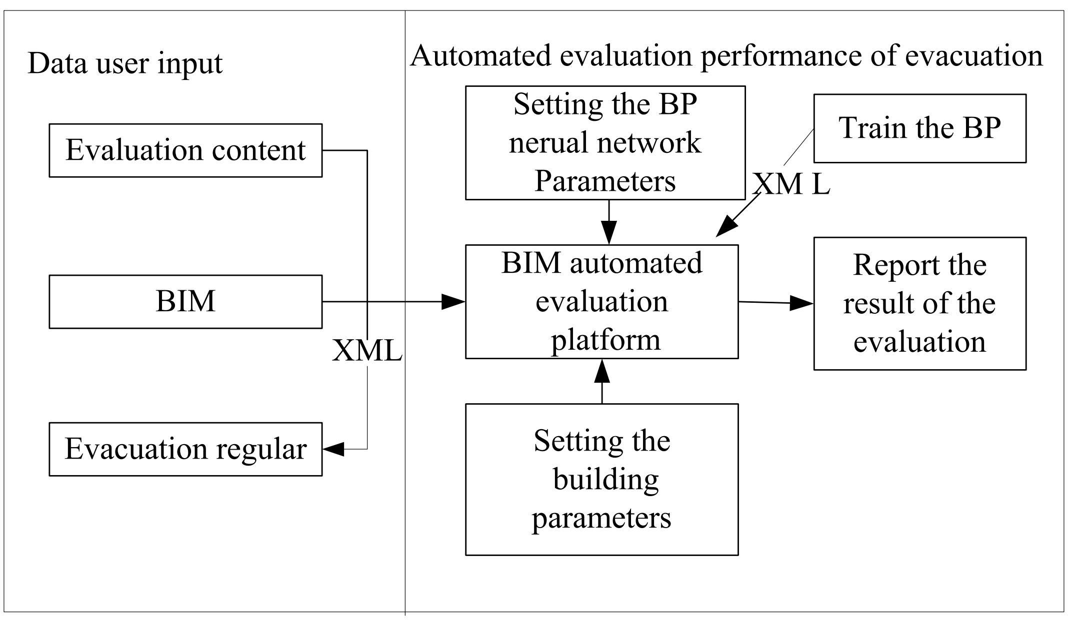


Figure 2.Framework for automated BIM evaluation platform.

The evaluation process based on BIM. To evaluate building evacuation performance, firstly, we need to establish the BIM model. Secondly, the platform automatically gets the data from the BIM model and evaluates the evacuation performance based on the data. Finally, it reports the result of the evaluation. In this paper, the process of evaluation is shown in Figure 3. Loaded train samples, then train the BP algorithm and storage the train result, used the train result can evaluate evacuation performance of a building.

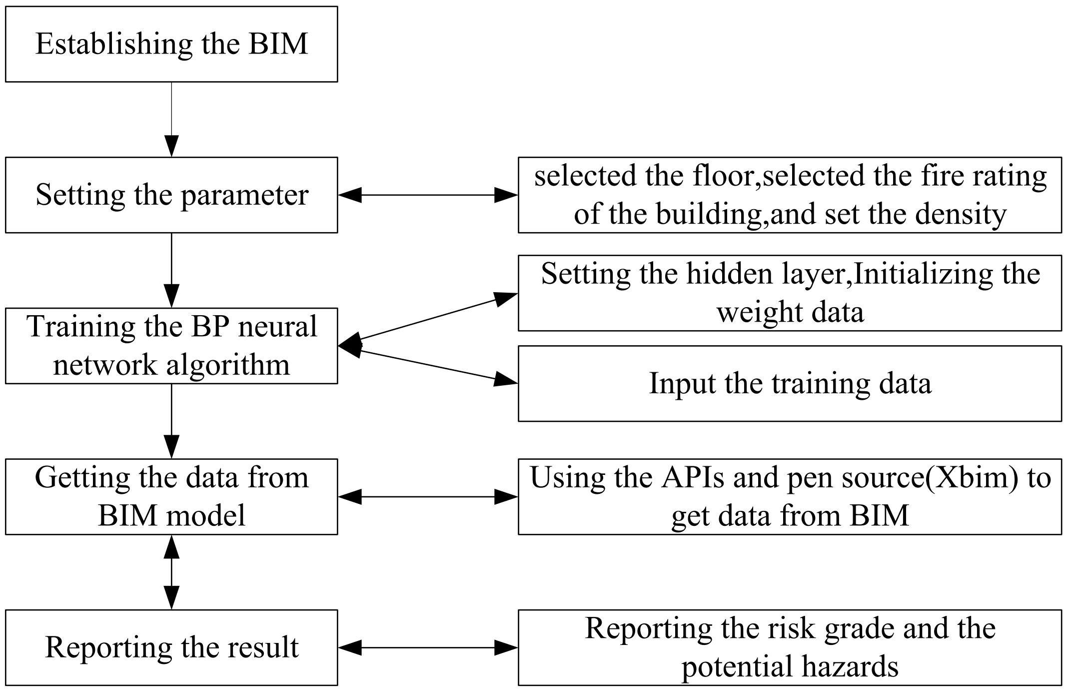


Figure 3.The process of evaluation.

CASE STUDY FOR VALIDATION

This section presents a validation of the platform through a case study. We used a real world building to validate the method. A case study used the BP neural network and BIM to evaluate the evacuation performance of the building. The project is a large public building of Home Exposition, the building area of 120000 square meters, has six floors, five floors above ground. The details of the case are as follows.

Establish building information modeling. A high level of detail BIM model is established as shown in Figure 4. The level of detail BIM model accord to the 'Building Information Modeling Design Standard for Civil Building' of Beijing 2013, we established the BIM model for LOD5. Besides included geometric and physical information, the BIM model also included the information of operation and maintenances of components and facilities.

Set evaluation information of the building. Set building style: selected the floor, selected the fire rating of the building, and set the density. In the case, we selected the public building-Marketplace, 'F1', 'First' of fire-rating, 'high' of density as shown in Figure 5.

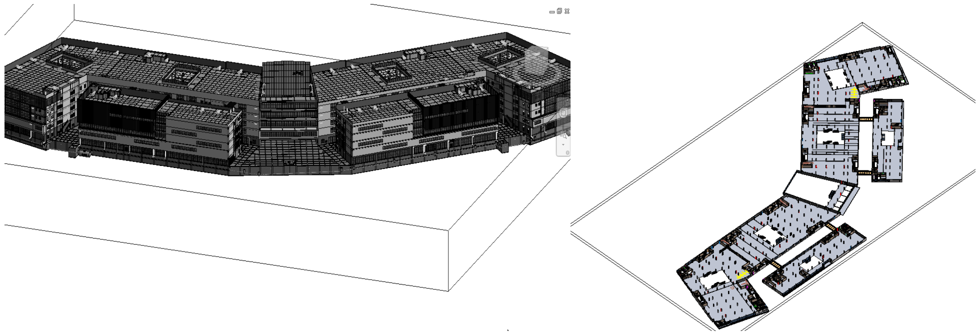


Figure 4.Building information modeling.

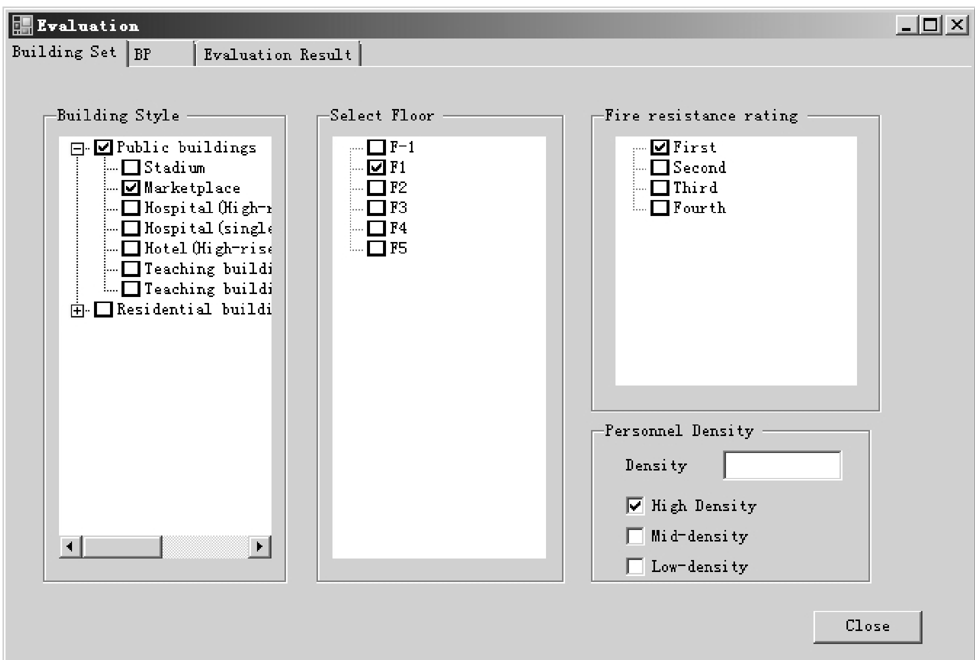


Figure 5.Set evaluation information of building.

Train BP neural network algorithm. According to the building style, automatically loaded the train samples from XML file that the train samples as shown in Table 2. According to the building style, we can create training samples, which can get great evaluation result. For example by large public buildings, as shown in Table 2, each grade building has 100 groups, in all 300 groups. In the table, the number '1' is marked as the low risk, '0.5' is marked as mid-risk, '0.1' as high-risk.

For training the algorithm, we initialize the weight matrix by assigned a random number to the weight matrix V_1, V_2 of the hidden layer and the weight matrix W of the output layer. According to experiment, the first hidden layer has 15 neurons and the second hidden layer has 9 neurons. Study efficiency is 0.12, momentum factor is 0.1, error is 0.001 and the iteration is 5000, in Figure 6.

Report evacuation performance. Used regulation that depicted in section 'scope and algorithm' to calculate the factor, then, load the data to the model of BP neural network. The result of evaluation is shown in Figure 6. In the evaluation result, near '1' is marked as the low risk, near '0.5' is marked as mid-risk, near '0.1' as high-risk. Except the risk report, the potential hazards were reported as shown in Figure 7.

Table 2.Train Samples.

Number	A1	A2	A3	…	A17	A18	…	A25	A26	A27	Result
1	0.98	0.97	0.95	…	0.98	0.98	…	0.95	1	0.4	1
2	0.93	0.96	0.92	…	0.97	0.94	…	0.96	0.3	0.88	1
3	0.91	0.95	0.96	…	0.99	0.94	…	0.96	0.2	1.12	1
⋮	:	:	:	:	:	:	:	:	:	:	:
101	0.82	0.81	0.81	…	0.85	0.87	…	0.93	0.65	1.1	0.5
102	0.81	0.86	0.87	…	0.83	0.88	…	0.86	0.38	0.9	0.5
103	0.88	0.97	0.89	…	0.97	0.91	…	0.85	0.66	1.5	0.5
⋮	:	:	:	:	:	:	:	:	:	:	:
298	0.93	0.30	0.85	…	0.92	0.87	…	0.86	0.66	1.5	0.1
299	0.13	0.25	0.74	…	0.66	0.57	…	0.74	0.46	0.84	0.1
300	0.86	0.82	0.67	…	0.88	0.89	…	0.35	0.86	0.31	0.1

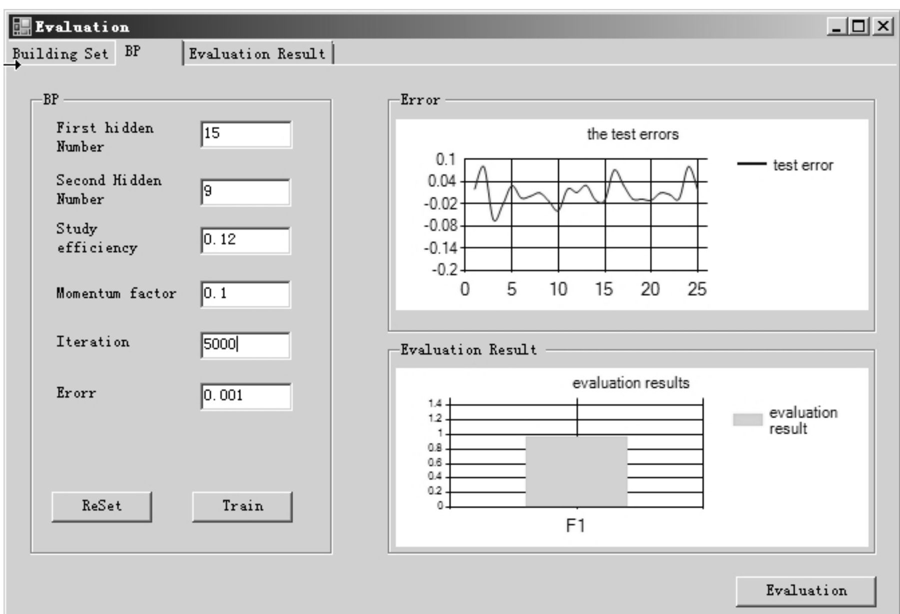
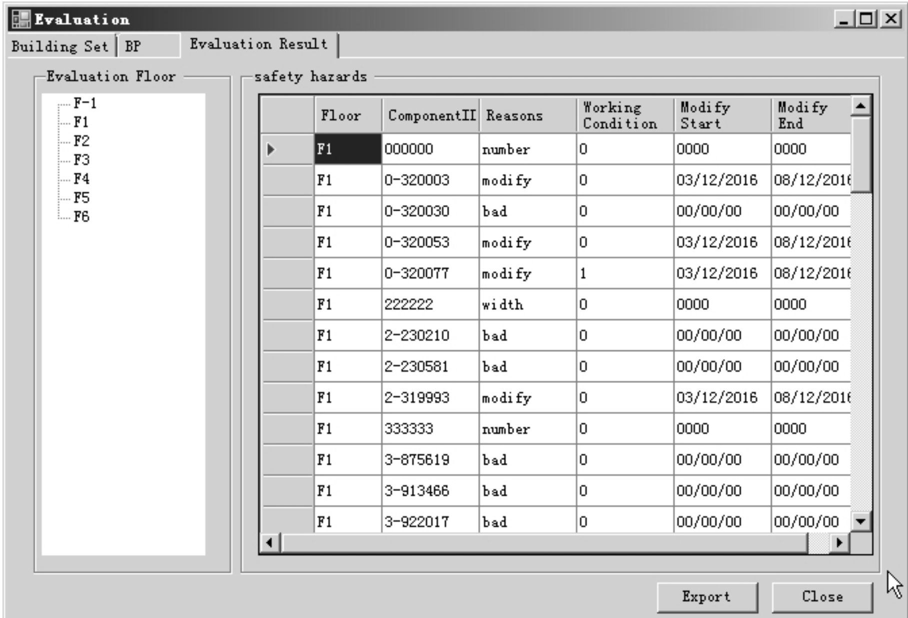


Figure 6.Parameters of the BP neural network and evaluation result.

In the risk report, we show the report such as floors, component ID, and reason about risk, working condition etc. In the Figure 7, if the component ID is '000000', it is the first factor 'distance to safety exit (A1)' in Table 1. The number such as 0-320003, before '-' the number '0' agent the 'A1', '320003' is the component number in the BIM model. The column 'reason' in Figure 7 shows the reason of risk. The column 'working condition' in Figure 7 shows the status of the component or facility. The column 'modify start' and 'modify end' show the detail modify information of component or facility.



Floor	ComponentII	Reasons	Working Condition	Modify Start	Modify End
F1	000000	number	0	0000	0000
F1	0-320003	modify	0	03/12/2016	08/12/201
F1	0-320030	bad	0	00/00/00	00/00/00
F1	0-320053	modify	0	03/12/2016	08/12/201
F1	0-320077	modify	1	03/12/2016	08/12/201
F1	222222	width	0	0000	0000
F1	2-230210	bad	0	00/00/00	00/00/00
F1	2-230581	bad	0	00/00/00	00/00/00
F1	2-319993	modify	0	03/12/2016	08/12/201
F1	333333	number	0	0000	0000
F1	3-875619	bad	0	00/00/00	00/00/00
F1	3-913466	bad	0	00/00/00	00/00/00
F1	3-922017	bad	0	00/00/00	00/00/00

Figure 7.Potential hazards.

DISCUSSION AND CONCLUSION

The building manager can use the platform to improve the building safety management. BIM model can provide the data for the automated evaluation. Different 2D model, BIM model can provide the geometry and physical information of the components and facilities. The train sample is a key issue for the method. Through practices of the samples data, an intelligent evaluation method is realized. Adjusted the BIM model in time, the propose approach can evaluate in time. The propose approach can assist the building safety management to prevent the safety hazard. In the case study, the result shows the method of using BIM and BP neural network can evaluate the evacuation performance of buildings. The method can decrease human influence.

This paper presents a framework and method to evaluate the building evacuation performance based on BIM. The study successfully demonstrated that the building evacuation performance for the building safety manager. The reason of the risk of building can be used to help a building manager. However, the evaluation factor and the train samples are not perfect. Adjusted BIM model also requires a user, it cannot automatically adjust.

Future, we research may overcome the discussed limitations. We optimized evaluation factors to improve the efficiency of the evaluation. We use the RFID to identify the status of the component and facility.

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Analysis of Competitive Environment for Foreign Construction Enterprises in China Construction Market

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Abstract

The development of foreign construction enterprises in China construction market is facing fierce competition and severe challenges. Foreign construction enterprises cannot ignore the analysis of the environment while making development strategy. It needs foreign enterprises not only complying with the environmental changes, but also keeping pace with variation of the external environment and make right strategic decision in time. Ensure to obtain an impregnable position in the process of future development. Carried on the detailed analysis of competitive environment for foreign construction enterprise by using the porter five competitive model. Then, draw out the differences between the foreign construction enterprises and the local construction enterprises in China, and put forward advices of development strategy for foreign construction enterprise in China.

INTRODUCTION

In recent years, China's construction market is one of the largest and fastest construction market all over the world. Construction industry output value from 1.2498 trillion RMB in 2000, up to 176.7134 trillion RMB in 2014. From 2001 to 2014, the average growth of rate is 20.8%. The number of China's construction enterprises is 149471 in 2005 while 464975 in 2014.During this decade, China's construction enterprises increase 3.11 times. However, foreign construction enterprises in China from 954 in 2000 cut to 630 in 2014.The quantity of foreign construction enterprises reduced by almost a third. These data indicate that the number of overall construction enterprises is increasing, but the number of foreign construction enterprises is reducing.