Contractor Key Competitiveness Indicators: A China Study

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Abstract: A proper method to assess contractor competitiveness is important both for assisting clients in the selection of proper contractors and for assisting contractors in the development of more competitive bidding strategies. Previous studies have identified various indicators for assessing contractor competitiveness, and several assessment methods have been introduced. Nevertheless, these studies are limited because they are unable to tell which indicators are more important in different market environments. This paper identifies the key competitiveness indicators (KCIs) for assessing contractor competitiveness in the Chinese construction market. An index value is used to indicate the relative significance of various competitiveness indicators based on which KCIs are identified. The data applied in this study are from a survey of the construction industry in mainland China. The research findings provide valuable information for both existing businesses and the construction professionals who plan to compete for construction works in the Chinese market. The study provides useful references for further studies that compare the KCIs used in the Chinese construction industry and those used in other construction industries.

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Introduction

Various definitions for competitiveness have been presented in existing studies for describing an organization's ability to compete for business in various markets (e.g., IMD 2003; WEF 1996). Typically, an organization's competitiveness is defined as "the ability to produce goods and services that meet the test of international markets while citizens earn a standard of living that is both rising and sustainable over the long-run" (U.S. Competitiveness Policy Council 1992). According to other studies (e.g., Select Committee of the House of Lords 1985; Ivancevich et al. 1997), the essence of organizational competitiveness is a firm's ability to win in competitions.

Other studies have introduced various models for assessing contractor competitiveness (e.g., Flanagan and Norman 1982; Shen et al. 2003). The assessment results are normally used to assist project clients in selecting contractors and enable contractors to understand their strengths and weaknesses, thereby improving the contractor's effectiveness in formulating bidding strategies for future competitions. A typical method for assessing contractor competitiveness is to calculate a competitiveness value that is considered a function of several competitiveness indicators. The identification of contractor competitiveness indicators has been extensively covered in previous studies. The study by Holt et al. (1994) classifies competitiveness indicators under five groups: contractor's organization, financial considerations, management resources, past experience, and past performance. Each of these groups also includes various specific indicators. Hatush and Skitmore (1997) proposed a set of criteria classified in five categories for assessing contractor competitiveness, including financial soundness, technical ability, management capability, health and safety, and reputation. These studies have led to a recent study by Shen et al. (2003) that presents a more comprehensive set of contractor competitiveness indicators in the development of a model for calculating a contractor's total competitiveness value (TCV). Contractor competitiveness indicators are grouped into six categories in the TCV model: social influence, technical ability, financing ability and accounting status, marketing ability, management skills, and organizational structure and operations.

However, applications of the competitiveness indicators introduced in previous studies are limited. Typically, there has been no investigation of the relevance of competitiveness indicators to different types of projects. In fact, project clients have different priorities based on various project objectives, and contractors must have different capabilities for different types of projects. Therefore, the project type should also be considered when contractor competitiveness is examined. This is echoed in the study by Flanagan and Norman (1982), which suggests that bidding is not only affected by price but also by the type of project concerned.

It also appears that no study exists that examines the relative importance of individual competitiveness indicators. Thus, it is difficult to determine key indicators in certain projects. For example, the TCV model includes 96 indicators. Hambrick (1984) argued that a theory would have little explanatory power if the large number of variables could not be reduced to a manageable

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Table 1. A List of Contractor Competitiveness Indicators

(1) Tendering price;	(17) Plant and equipment resources;	(32) Site management ability;
(2) Construction time;	(18) Information technology;	(33) Availability and effectiveness of safety and health system;
(3) Quality plan;	(19) Relationship with governmental departments;	(34) Past safety management performance;
(4) Construction program;	(20) Relationship with project clients;	(35) Availability and effectiveness of environment management system;
(5) Environment protection plan;	(21) Relationship with subcontractors and suppliers;	(36) Past environmental management performance;
(6) Safety plan;	(22) Relationship with the public;	(37) Availability and effectiveness of risk management system;
(7) Construction method;	(23) Availability of quality management system;	(38) Past risk management performance;
(8) Experience in operating similar projects;	(24) Effectiveness of quality policy;	(39) Existing human resources;
(9) Plant availability;	(25) Past quality performance;	(40) Human resource development program;
(10) Availability of key personnel;	(26) Effectiveness of time-management system;	(41) Effectiveness of organization operation;
(11) Financing ability;	(27) Past time control performance;	(42) Suitability of organizational structure;
(12) Financial stability;	(28) Availability of cost controlling system;	(43) Size of the organization;
(13) Financial status;	(29) Past cost control performance;	(44) Duration of the organization establishment;
(14) Bank credit;	(30) Availability of contract administration system;	(45) Image and reputation of the organization.
(15) Technology capacity;	(31) Past performance in completing contract;	
(16) Technology development plan;		

few. Therefore, the TCV model will become more applicable if the key indicators within the model are identified.

This study extends the TCV model to determine the key contractor competitiveness indicators (KCIs) for different types of projects in the Chinese construction market. An index value is used for measuring the significance value of individual competitiveness indicators, allowing the key competitiveness indicators to be identified. Data used for the analysis in this study are collected through a survey to the construction industry in China. The study addresses an important issue for helping construction professionals, particularly those from overseas, to understand the practice of assessing contractor competitiveness in the Chinese construction market. The results herein become even more pressing in line with the development of China's accession to the World Trade Organization (WTO), which has been attracting an increasing number of overseas construction practitioners to operate business in the market.

Research Methodology

This study was undertaken through the following major research activities and methods: formulating a list of contractor competitiveness indicators, defining the method for evaluating indicator significance, and constructing a quantitative model for identifying the KCIs.

Formulating a List of Contractor Competitiveness Indicators

The contractor competitiveness indicators presented in previous studies (Holt et al. 1994; Hatush and Skitmore 1997; Shen et al. 2003) were reviewed and compiled into a comprehensive list of contractor competitiveness indicators. Tests were conducted through workshops on the suitability of these indicators for the Chinese construction industry. Four workshops were held for two project clients and two large contractors in Shenzhen, China. Four to seven professionals attended each individual workshop, during which the attendants were invited to comment on the suitability and clarity of the suggested indicators. The attendants contributed valuable suggestions during the workshops based on the modifications made. The final list of competitiveness indicators was formulated as presented in Table 1.

Defining the Method for Evaluating Indicator Significance

A typical methodology for identifying the key factors among a number of individual factors is to evaluate each factor's relative significance value (Chau et al. 1999; Moungnos and Charoenngam 2003). The Likert scale is commonly used for rating the relative significance of individual factors through examining experts' opinion (e.g., Chan and Kumaraswamy 1997; Shen and Liu 2003). This scale method was used in this study to conduct the opinion survey on the significance of competitiveness indicators to the success of implementing a construction project by a contractor. As the term "success" has a different meaning for different types of projects that have different priorities among various project objectives, "success" is decomposed into multiple project success criteria: cost control, quality performance, time management, safety management, and environmental performance. These criteria have different priorities when different types of projects are considered. Thus, survey respondents were invited to give their opinions on the relative significance between project success criteria when referring to different types of projects.

Project Type

Construction project type is an important factor affecting the plan of project objectives and the choice of contractor. There are various classifications on construction project type. A typical classification, by Ray-Jones and Clegg (1976), presents nine categories of construction projects. These include civil engineering facilities, industrial facilities, administrative facilities, health facilities, recreational facilities, religious facilities, educational and scientific facilities, residential facilities, and common facilities. This classification is given mainly according to the types of users of construction projects. Another typical project classification adopted in China is composed of twelve groups: building and residential facilities (P_1), road facilities (P_2), railway facilities (P_3), water transport facilities (P_4), hydroelectricity facilities (P_5), power facilities (P_6), mining projects (P_7), smeltery projects (P_8), petrochemical engineering projects (P_9), urban infrastructure projects (P_{10}), facilities for communication (P_{11}), and mechanical and electric installation in building projects (P_{12}) (MOC 2001). This classification emphasizes project characteristics and is more direct in presenting project nature. It was used for the analysis in this study.

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Table 2. A Sample of the Questionnaire Response in Part-One Survey

Project type	$\frac{C_1}{C_2}$	$\frac{C_1}{C_3}$	$\frac{C_1}{C_4}$	$\frac{C_1}{C_5}$	$\frac{C_2}{C_3}$	$\frac{C_2}{C_4}$	$\frac{C_2}{C_5}$	$\frac{C_3}{C_4}$	$\frac{C_3}{C_5}$	$\frac{C_4}{C_5}$
P_1-Building and residential facilities	1	1	6	7	2	5	7	6	7	3
P_2-Road facilities	1	2	5	6	2	6	5	6	6	2
P_3-Railway facilities	1	1	5	6	2	5	6	5	7	3
P_4-Water transport facilities	2	2	6	7	2	7	8	7	6	4
P_5-Hydroelectricity facilities	2	1	5	7	2	7	7	9	6	1
P_6-Power facilities	1	1	6	6	1/2	6	6	8	6	2
P_7-Mining projects	1/2	1	3	4	3	4	5	6	5	3
P_8-Smeltery projects	1	1	5	4	2	7	5	8	5	1
P_9-Petrochemical engineering project	2	2	6	4	1	6	5	8	5	1
P_{10}-Urban infrastructure projects	1/2	1/2	6	4	1	3	8	6	6	3
P_{11}-Facilities for communication	3	2	4	7	1	9	9	9	9	5
P_{12}-Mechanical and electric installation in building project	3	2	5	7	1/2	7	9	9	9	7

Note: C_1=cost control; C_2=quality management; C_3=time management; C_4=safety management; C_5=environmental protection.

The value C_x/C_y represents expert's judgment on the relative importance of C_x over C_y. The following are the guidelines for helping respondents in allocating relative values (Saaty 1980):

1: Equal importance

3: Weak importance of one over another

5: Essential or strong importance

7: Very strong or demonstrated importance

9: Avsolute importance

2,4,6,8: Intermediate values between adjacent scale values

Reciprocals of above nonzero: If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.

Multiple Project Success Criteria

The success criteria for implementing a construction project have been broadened from the traditional cost control (C_1), quality management (C_2), and time management (C_3) to include safety management (C_4) and environmental protection (C_5). On the other hand, researchers (e.g., BEDC 1983; Watkinson 1992) suggest that rarely can all project success criteria be fully satisfied at the same time. Therefore, a trade-off between various criteria is often necessary to ensure the overall success of a project. A typical approach for considering the trade-off is to introduce a weighting value to describe the relative significance between the criteria to the success of a particular type of project.

Constructing a Quantitative Model for Identifying KCIs

KCIs are found by establishing relative significance between indicators. To evaluate the relative significance between the 45 competitiveness indicators listed in Table 1, denoted as $I_i=(I_1,\ldots,I_{45})$, an index value for each indicator is calculated using a quantitative model. In fact, identifying the relative significance between variables by calculating their index values is a commonly adopted methodology (Chau et al. 1999; Shen and Liu 2003). The index model is constructed as follows:

$$S_i^k = \sum_{j=1}^{5} \omega_j^k x_{ij} \tag{1}$$

Where S_i^k=the index value of the competitiveness indicator I_i ($i=1,2,\ldots,45$) when the project type P_k ($k=1,2,\ldots,12$) is procured; ω_j^k=the weighting value between project success criteria C_j ($j=1,2,\ldots,5$) when project type P_k is concerned; x_{ij}=the significance of competitiveness indicator I_i to the achievement of project success criterion C_j. The index value of the competitiveness indicators has taken into account the type of project and the relative significance between project success criteria. Thus, the KCIs can be identified by examining the index values derived from Eq. (1). To conduct the calculations of the equation, data are needed for generating the values of the parameters ω_j^k and x_{ij}. The survey conducted to collect the data is presented in the following section.

Data Survey

A questionnaire survey was used to collect the data for the calculations of KCI Eq. (1). The questionnaire was designed to consist of two parts. The first part concerns the weightings between the project success criteria for specific project types. The second part of the survey concerns the significance of a competitiveness indicator to the achievement of project success criteria. Practitioners participating in the survey were carefully identified to ensure that they had a good understanding of and experience in conducting different types of projects, including residential building works, industrial works, and infrastructure facilities. Project clients and their project managers are in the best position to respond to the first part of the survey, and contractors are suitable for the second part of the survey. Thus, part one and part two of the questionnaire were sent to two groups of practitioners, with each group consisting of 200 candidates. These practitioners were selected from major cities in China, including Beijing, Shanghai, Guangzhou, Chongqing, Shenzhen, Nanjing, and Hangzhou. The survey was carried out from July to November 2003. Selective interviews were conducted from December 2003 to January 2004 for collecting further supporting data for analysis.

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Table 3. A Sample Response to Part-Two Survey

Competitiveness indicators I_i ($i=1,\ldots,45$)	Indicator significance of project criteria C_j				
	C_1	C_2	C_3	C_4	C_5
I_1-Tendering price	10	6	6	0	5
I_2-Construction time	10	9	10	7	8
I_3-Quality plan	8	9	10	9	8
I_4-Construction program	8	8	10	9	7
I_5-Environment protection plan	8	2	8	8	10
I_6-Safety plan	8	3	7	10	9
I_7-Technology plan	8	8	8	7	6
I_8-Experience in operating similar projects	10	10	10	10	10
I_9-Plant availability	9	8	10	8	7
I_{10}-Availability of key personnel	6	10	10	10	5
I_{11}-Financing ability	10	6	10	6	5
I_{12}-Financial stability	10	9	10	8	5
I_{13}-Financial status	10	8	10	8	5
I_{14}-Bank credit	10	0	9	6	0
I_{15}-Technology capacity	10	9	10	8	6
I_{16}-Technology development plan	10	10	10	6	5
I_{17}-Plant and equipment resources	10	6	10	9	6
I_{18}-Information technology	6	8	6	5	5
I_{19}-Relationship with govemmental departments	10	0	0	0	8
I_{20}-Relationship with project clients	10	0	8	5	5
I_{21}-Relationship with subcontractors and suppliers	10	10	10	10	6
I_{22}-Relationship with public	8	8	8	6	6
I_{23}-Availability of quality management system	10	10	10	10	8
I_{24}-Effectiveness of quality policy	8	10	10	10	6
I_{25}-Past quality performance	2	2	2	2	2
I_{26}-Effectiveness of time management system	10	8	10	8	6
I_{27}-Past time control performance	2	2	10	3	2
I_{28}-Availability of cost controlling system	10	8	8	6	5
I_{29}-Past cost control performance	10	8	8	6	5
I_{30}-Availability of contract administration system	10	8	0	8	5
I_{31}-Past performance in completing contract	10	8	8	6	6
I_{32}-Site management ability	10	10	10	10	8
I_{33}-Availability and effectiveness of safety and health system	8	6	6	10	5
I_{34}-Past safety management performance	2	2	5	10	2
I_{35}-Availability and effectiveness of environment management system	10	6	6	6	10
I_{36}-Past environmental management performance	8	0	0	6	10
I_{37}-Availability and effectiveness of risk management system	10	2	2	2	2
I_{38}-Past risk management performance	10	2	2	2	2
I_{39}-Existing human resources	8	9	9	9	2
I_{40}-Human resource development program	9	8	8	8	2
I_{41}-Effectiveness of organization operation	10	10	10	10	2
I_{42}-Suitability of organizational structure	8	8	8	8	5
I_{43}-Size of the organization	10	6	8	6	5
I_{44}-Duration of the organization establishment	6	6	6	6	5
I_{45}-Image and reputation of the organization	10	10	10	10	10

In the first part of the survey, which aims to investigate the relative significance between the five major project success criteria (cost control, quality management, time management, safety management, and environmental protection), when a specific type of project is referred to, 79 effective responses were received. For to each type of project, respondents were asked to judge the relative significance in pairs between project success criteria. A sample questionnaire response is shown in Table 2. The analytical hierarchy process (AHP) was employed to analyze the data in the survey. AHP is a well-received method used to synthesize judgments and derive priorities among criteria (Saaty 1980). This method has a unique characteristic of making a pair-wise comparison among the criteria to ensure a reliable result of judgment on the priorities between the criteria.

In the second part of the survey, the respondents were invited to indicate the level of significance of each competitiveness indi-

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Table 4. Weightings Judged by Individuals (Samples)

Respondent	Project type	Weightings ω_{1v}^k	ω_{2v}^k	ω_{3v}^k	ω_{4v}^k	ω_{5v}^k
1	P_1	0.3013	0.2709	0.3112	0.0605	0.0561
	P_2	—	—	—	—	—
	P_{12}	0.2900	0.3061	0.3121	0.0505	0.0283
2	P_1	—	—	—	—	—
	P_2	0.2422	0.3163	0.3207	0.0475	0.0736
	P_{12}	0.2922	0.2985	0.3111	0.0517	0.0345
79	P_1	0.2852	0.2577	0.3114	0.0736	0.0721
	P_2	0.2277	0.3073	0.3325	0.0414	0.0880
	P_{12}	0.2919	0.3033	0.3105	0.0408	0.0415

cator to the achievement of project success criteria. Respondents were advised to allocate a value by selecting a figure between 0 and 10, with 10 indicating the highest significance, 0 indicating no relevance, and the middle values (9,8,7,6,5,4,3,2,1) representing different levels of significance between highest and zero. Seventy three effective replies were received, and Table 3 presents a sample response.

Data Analyses

By feeding the data presented in the previous section into KCI Eq. (1), the following calculation results are obtained:

Establishing Weightings between Project Success Criteria

The variable ω_j^k in KCI Eq. (1) denotes the weighting values between project success criteria C_j when project type P_k is concerned. The values of ω_j^k are obtained by averaging the individual judgment results from the 79 effective responses in the first part of the survey through the following equation:

$$\omega_j^k = \frac{\sum_{v=1}^{n} \omega_{jv}^k}{79} \qquad (2)$$

Where ω_{jv}^k=individual judgment by respondent v on the value of ω_j^k. The value of ω_{jv}^k was generated by applying AHP method to analyze the data collected from individual respondents. AHP method involves three major procedures, including formulating judgment matrix, calculating the eigenvector, and checking consistency (Saaty 1980). The software package *Expert Choice* was used in this study as sophisticated calculations were involved in these procedures. Table 4 presents the calculation results of this software package. For example, the figures in the first row in the table—0.3013, 0.2709, 0.3112, 0.0605, and 0.0561—represent the judgment by the respondent no. 1 on the weightings between the five project success criteria for the residential building project type (P_1). The areas marked with "-" in the table represent invalid results after consistency checking using AHP. Consistency checking ensures that the respondents' subjective judgments are consistent and acceptable. By applying the data in Table 4 to Eq. (2), the values ω_j^k are established, as presented in Table 5.

The calculation results in Table 5 show that different priorities are given to the various project objectives of the different project types. The results also show that the traditional project objectives—time, cost, and quality—are still considered far more important than the newly emerged objectives of safety management and environmental protection. Safety and environment have not yet been treated as important objectives in the Chinese construction practice.

Project Groupings

The data in Table 5 was analyzed to find out whether weighting distributions were similar among different groups of project types. If this similarity does exist, the twelve types of projects described previously can be integrated into fewer groups. Integration could simplify analysis of the KCIs for different types of projects. For this purpose, the cluster analysis technique was applied to regroup project types. Cluster analysis is a proven effective technique in identifying and grouping similarities among individuals. By employing the data in Table 5 to the cluster analysis statistical package *Statistica v6.0*, project groupings were generated, as shown in Fig. 1.

Fig. 1 illustrates all possible groupings (clusters) among the twelve types of projects according to the similarities of the weightings between project success criteria. According to the cluster analysis principle, the most effective grouping between individuals will give the biggest change of Euclidean distance. The figure shows that the biggest change of Euclidean distance

Table 5. Weightings between Project Success Criteria in Referring to Types of Projects

Project type (P_k, k=1…12)	Weighting values ω_1^k-cost	ω_2^k-quality	ω_3^k-time	ω_4^k-safety	ω_5^k-env.
P_1-Building and residential facilities	0.3013	0.2709	0.3112	0.0605	0.0561
P_2-Road facilities	0.2399	0.3146	0.3222	0.0483	0.0719
P_3-Railway facilities	0.2389	0.3126	0.3225	0.0502	0.0714
P_4-Water transport facilities	0.2392	0.3142	0.3146	0.0495	0.0885
P_5-Hydroelectricity facilities	0.2131	0.3235	0.3258	0.0475	0.0970
P_6-Power facilities	0.2391	0.2748	0.3023	0.0652	0.1020
P_7-Mining projects	0.2589	0.2736	0.2814	0.0987	0.0974
P_8-Smeltery projects	0.2547	0.2744	0.3124	0.0514	0.1103
P_9-Petrochemical engineering projects	0.2511	0.2714	0.2766	0.0977	0.1135
P_{10}-Urban infrastructure projects	0.2420	0.3289	0.3114	0.0710	0.0682
P_{11}-Facilities for communication	0.2601	0.2559	0.3246	0.0837	0.0857
P_{12}-Mechanical and electric installation in building projects	0.2911	0.3023	0.3116	0.0511	0.0319

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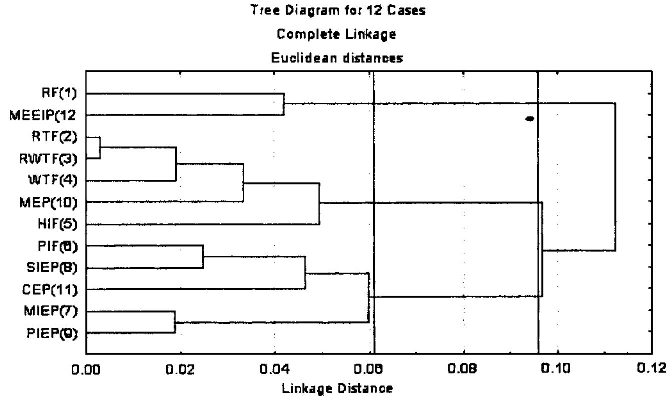

Fig. 1. Project groupings by using cluster analysis method

occurs when the grouping of project type changes from three clusters to other number of clusters; thus, it is most effective to integrate the projects into three clusters:

- G_1 (P_1, P_{12}): building and residential facilities; mechanical and electric installation in building projects;
- G_2 ($P_2, P_3, P_4, P_5, P_{10}$): road facilities; railway facilities; water transport facilities; hydroelectricity facilities; urban infrastructure projects; and
- G_3 ($P_6, P_7, P_8, P_9, P_{11}$): power facilities; mining projects; smeltery projects; petrochemical engineering projects; facilities for communication.

Weighting values between project success criteria are calculated for different project clusters by averaging the individual project-based weighting values in Table 5:

$$\omega_j^{G_1} = (\omega_j^1 + \omega_j^{12})/2 \tag{3}$$

$$\omega_j^{G_2} = (\omega_j^2 + \omega_j^3 + \omega_j^4 + \omega_j^5 + \omega_j^{10})/5 \tag{4}$$

$$\omega_j^{G_3} = (\omega_j^6 + \omega_j^7 + \omega_j^8 + \omega_j^9 + \omega_j^{11})/5 \tag{5}$$

The calculation results from Eqs. (3)–(5) are shown in Table 6. The results show that cost, quality, and time are all closely important to implement cluster 1 (G_1) projects which include building and residential facilities and installation works in building projects. Nevertheless, construction time is considered most important for this group of projects. This may reflect the construction practice in China, where the market for building and residential projects has been booming and construction time has been the key for ensuring that good market time would not be missed. In the implementation of cluster 2 (G_2) projects, which consist of the projects for public transportation, construction quality and time are considered more important than construction costs. This is echoed in the study by Huang et al. (2005), which suggests that the government in China most emphasizes quality for the implementation of public sector projects. Projects in cluster 3 (G_3) mainly concern industrial facilities. For this cluster, time is the most important factor because the earlier the projects are completed, the faster clients can generate returns.

Significance of Indicators to the Achievement of Project Success Criteria

To conduct the calculations using Eq. (1), the significance of individual competitiveness indicators to the achievement of project success criterion, denoted as x_{ij}, needs to be established. The values of x_{ij} are generated by averaging the individual judgment results from the 73 effective responses in the second part of the survey (a sample response is given in Table 3):

$$x_{ij} = \frac{\sum_{v=1}^{73} x_{ij}^v}{73} \tag{6}$$

Where x_{ij}^v=the value allocated by the individual respondent v to the significance of competitiveness indicator I_i in the achievement of the project success criterion C_j. The calculation results from Eq. (6) are presented in Table 7. The implications of the results are twofold: (1) A same competitiveness indicator has different significance value to the achievement of different project success criteria. For example, the significance value of the indicator "tendering price" (I_1) to the project success criterion "project cost" is 9.25 while that to "safety management" is 4.25. This implies that "tendering price" is more important for controlling project cost than that for safety management. (2) Different competitiveness indicators have different significance values for the same project success criterion. For example, the indicator "tendering price" (I_1) is considered very important to the project success criterion "project cost," with the significance level of 9.25, while the indicator "construction program" (I_4) is less important to project cost, with the significance level of 6.75. When a project client selects a contractor mainly by considering the criterion "project cost," a contractor (A) offering lower tendering price will be considered more competitive than a contractor (B) offering better construction program. However, when the client applies the criterion "safety management," the indicator "tendering price" has a significance level of 4.25 to the achievement of the criterion and the significance level of the indicator "construction program" is 5.81. Thus contractor B is better than A. Therefore, contractors' com-

Table 6. Weightings between Project Success Criteria in Referring to Project Clusters

Project groupings	Weighting values ($\omega_j^G, j=1..5, G=G_1, G_2, G_3$)				
	ω_1^k-cost	ω_2^k-quality	ω_3^k-time	ω_4^k-Safety	ω_5^k-Env.
Cluster 1 (**G_1**) (building and residential facilities; mechanical and electric installation in building project)	0.2962	0.2866	0.3114	0.0588	0.0440
Cluster 2 (**G_2**) (road facilities; railway facilities; water transport facilities; hydroelectricity facilities; urban infrastructure projects)	0.2346	0.3188	0.3193	0.0533	0.0794
Cluster 3 (**G_3**) (power facilities; mining projects; smeltery projects; petrochemical engineering project; facilities for communication)	0.2528	0.2700	0.2995	0.0793	0.1018

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Table 7. Significance Values of Competitiveness Indicators to the Achievement of Project Success Criteria

Competitiveness indicators (I_i)	Significance value				
	x_{i1}	x_{i2}	x_{i3}	x_{i4}	x_{i5}
I_1	9.25	8.16	8.38	4.25	6.25
I_2	9.02	8.01	9.24	3.81	3.94
I_3	8.32	9.15	6.35	4.19	4.00
I_4	6.75	6.69	7.50	5.81	4.06
I_5	4.56	3.31	4.38	4.63	7.56
I_6	4.69	3.81	4.13	8.56	3.38
I_7	7.00	8.31	7.63	6.56	4.63
I_8	7.89	8.01	8.20	8.02	5.38
I_9	5.31	4.69	5.38	3.81	2.63
I_{10}	8.04	7.31	6.89	4.50	2.88
I_{11}	5.94	3.31	5.06	3.38	2.31
I_{12}	5.33	3.20	5.53	2.60	2.07
I_{13}	5.20	4.07	5.27	2.40	1.60
I_{14}	3.80	2.73	3.20	2.67	2.40
I_{15}	7.56	7.44	7.00	5.50	4.00
I_{16}	5.73	8.13	6.20	4.60	3.80
I_{17}	5.87	5.20	7.53	3.60	2.33
I_{18}	5.93	6.20	5.67	4.20	2.87
I_{19}	5.56	3.44	5.00	2.00	3.44
I_{20}	7.27	3.93	6.27	3.93	3.20
I_{21}	5.73	5.93	6.33	4.87	4.07
I_{22}	3.80	3.53	4.33	3.60	4.53
I_{23}	4.80	7.47	5.33	4.67	3.20
I_{24}	4.60	7.73	6.00	5.40	2.53
I_{25}	2.73	6.47	3.87	3.67	2.07
I_{26}	3.73	5.20	7.27	3.20	1.87
I_{27}	4.69	5.50	8.13	3.38	2.25
I_{28}	7.53	5.73	6.40	3.93	2.40
I_{29}	7.06	6.13	6.31	5.19	2.94
I_{30}	8.47	5.13	4.67	3.93	2.13
I_{31}	7.81	4.94	6.06	3.69	3.06
I_{32}	8.33	7.56	8.40	7.87	4.60
I_{33}	4.94	4.06	3.88	8.00	4.13
I_{34}	4.40	4.40	3.40	8.40	3.00
I_{35}	4.00	4.44	3.06	4.00	8.67
I_{36}	3.27	2.60	2.80	3.13	9.12
I_{37}	6.88	4.56	5.13	3.38	2.81
I_{38}	6.27	5.73	3.67	3.07	2.20
I_{39}	6.56	7.06	6.81	6.06	4.00
I_{40}	5.73	6.07	6.20	4.47	2.40
I_{41}	7.00	6.27	6.20	5.20	3.07
I_{42}	5.73	5.13	5.60	4.13	2.33
I_{43}	6.00	4.73	5.53	4.33	2.13
I_{44}	4.53	3.20	3.27	3.07	1.80
I_{45}	6.80	3.60	6.13	5.33	3.67

Table 8. Index Values of Competitiveness Indicators

	Significance score S_i^k (k=1, ..., 12; i=1, ..., 45)		
I_i (i=1..45)	Cluster I (P_1, P_{12})	Cluster II (P_3, P_4, P_5, P_{10})	Cluster III ($P_6, P_7, P_8, P_9, P_{11}$)
I_1	8.21	8.17	8.02
I_2	8.24	8.14	7.91
I_3	7.49	7.44	7.22
I_4	6.77	6.74	6.63
I_5	4.33	4.49	4.65
I_6	4.42	4.36	4.47
I_7	7.42	7.44	7.29
I_8	7.89	7.88	7.80
I_9	4.93	4.87	4.79
I_{10}	7.01	6.89	6.72
I_{11}	4.58	4.43	4.41
I_{12}	4.46	4.34	4.28
I_{13}	4.56	4.46	4.35
I_{14}	3.17	3.12	3.11
I_{15}	7.05	6.99	6.86
I_{16}	6.11	6.14	5.98
I_{17}	5.89	5.82	5.67
I_{18}	5.67	5.63	5.50
I_{19}	4.46	4.38	4.34
I_{20}	5.60	5.42	5.41
I_{21}	5.83	5.84	5.75
I_{22}	3.90	3.95	3.96
I_{23}	5.64	5.71	5.52
I_{24}	5.88	5.95	5.73
I_{25}	4.17	4.30	4.10
I_{26}	5.13	5.17	4.97
I_{27}	5.79	5.81	5.60
I_{28}	6.20	6.04	5.92
I_{29}	6.25	6.14	6.04
I_{30}	5.76	5.49	5.45
I_{31}	5.97	5.78	5.73
I_{32}	7.91	7.83	7.76
I_{33}	4.49	4.45	4.56
I_{34}	4.25	4.21	4.29
I_{35}	4.03	4.23	4.33
I_{36}	3.17	3.38	3.54
I_{37}	5.26	5.11	5.06
I_{38}	4.92	4.81	4.70
I_{39}	6.62	6.60	6.49
I_{40}	5.74	5.69	5.54
I_{41}	6.24	6.14	6.04
I_{42}	5.26	5.17	5.08
I_{43}	5.20	5.08	5.01
I_{44}	3.54	3.43	3.42
I_{45}	5.43	5.28	5.32

petitiveness is measured differently by different clients who procure different types of projects.

Calculating the Index Values of Competitiveness Indicators

The index values of competitiveness indicators can be calculated by applying the data in Table 6 and Table 7 to KCI Eq. (1), and the calculation results are shown in Table 8. The calculation results show that different competitiveness indicators have different significance values to a particular cluster of projects, this is echoed by the analysis in the previous section. For example, for implementing cluster 1 (G_1) projects, the indicator "tendering price" (I_1) is considered important with the significance level of 8.21, while the indicator "environment protection plan" (I_5) is not considered important, with the significance level of 4.33. This

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Table 9. Top-Ten Key Competitiveness Indicators in Referring to Types of Projects

	Cluster 1 projects (P_1, P_{12})		Cluster 2 projects (P_2, P_3, P_4, P_5, P_{10})		Cluster 3 projects (P_6, P_7, P_8, P_9, P_{11})	
Rank order	Indicator	Index value	Indicator	Index value	Indicator	Index value
1st	I_2	8.24	I_1	8.17	I_1	8.02
2nd	I_1	8.21	I_2	8.14	I_2	7.91
3rd	I_{32}	7.91	I_8	7.88	I_8	7.80
4th	I_8	7.89	I_{32}	7.83	I_{32}	7.76
5th	I_3	7.49	I_7	7.44	I_7	7.29
6th	I_7	7.42	I_3	7.44	I_3	7.22
7th	I_{15}	7.05	I_{15}	6.99	I_{15}	6.86
8th	I_{10}	7.01	I_{10}	6.89	I_{10}	6.72
9th	I_4	6.77	I_4	6.74	I_4	6.63
10th	I_{39}	6.62	I_{39}	6.60	I_{39}	6.49

helps to identify the KCIs for particular types of projects. On the other hand, according to calculation results, the significance of indicators to different clusters of projects varies. Considering the indicator "tender price" (I_1), its significance value is 8.21 to cluster 1 projects, while its significance value is 8.02 if bidding projects are in cluster 2.

Identification of Contractor KCIs

According to the index values in Table 8, competitiveness indicators listed in Table 1 are ranked. For example, Table 9 illustrates the top-ten indicators for three clusters of projects. While a rank list can indicate the relative importance between indicators, it can not tell how many of them should be considered as KCIs. Usually, a boundary will be defined for marking the indicators as critical or noncritical. The study by Chau et al. (1999) suggests using the top-ten factors in an index rank list as the critical factors. Shen and Liu (2003) use an arbitrary cut-off value to specify the boundary of critical factors. Nevertheless, using the arbitrary criterion could exclude the true critical factors, with index values slightly smaller than the designated boundary value, from the list. To mitigate this weakness, the cluster analysis technique is employed to form a flexible boundary by which the indicators in Table 8 are distinguished between critical, less critical, and noncritical. By adopting a flexible boundary, any two indicators having closer index values will be included in a same group. The analysis results, shown in Table 10, present three zones of competitiveness indicators: critical, less critical, and noncritical.

The data in Table 10 show that the KCIs in the three indicator zones are different across the three project clusters. For example, 24 KCIs fall in the critical zone for cluster 1 projects, 22 for cluster 2 projects, and 18 KCIs for cluster 3 projects. These results provide valuable references for selecting indicators in assessing contractors' competitiveness for different types of projects. These research findings contribute to more effective application of the TCV model (Shen et al. 2003), which aims to select the most suitable contractors for particular types of contracts.

Table 10. Contractor Competitiveness Indicators in Critical, Less Critical, and Noncritical Zones

	Cluster 1 projects		Cluster 2 projects		Cluster 3 projects	
Rank of KCIs	Indicator	Index value	Indicator	Index value	Indicator	Index value
1st	I_2	8.24	I_1	8.17	I_1	8.02
2nd	I_1	8.21	I_2	8.14	I_2	7.91
3rd	I_{32}	7.91	I_8	7.88	I_8	7.80
4th	I_8	7.89	I_{32}	7.83	I_{32}	7.76
5th	I_3	7.49	I_7	7.44	I_7	7.29
6th	I_7	7.42	I_3	7.44	I_3	7.22
7th	I_{15}	7.05	I_{15}	6.99	I_{15}	6.86
8th	I_{10}	7.01	I_{10}	6.89	I_{10}	6.72 ①
9th	I_4	6.77	I_4	6.74 ①	I_4	6.63
10th	I_{39}	6.62	I_{39}	6.60	I_{39}	6.49
11th	I_{29}	6.25 ①	I_{41}	6.14	I_{41}	6.04
12th	I_{41}	6.24	I_{16}	6.14	I_{29}	6.04
13th	I_{28}	6.20	I_{29}	6.14	I_{16}	5.98
14th	I_{16}	6.11	I_{28}	6.04	I_{28}	5.92
15th	I_{31}	5.97	I_{24}	5.95	I_{21}	5.75
16th	I_{17}	5.89	I_{21}	5.84	I_{24}	5.73
17th	I_{24}	5.88	I_{17}	5.82	I_{31}	5.73
18th	I_{21}	5.83	I_{27}	5.81	I_{17}	5.67
19th	I_{27}	5.79	I_{31}	5.78	I_{27}	5.60
20th	I_{30}	5.76	I_{23}	5.71	I_{40}	5.54
21st	I_{40}	5.74	I_{40}	5.69	I_{23}	5.52
22nd	I_{18}	5.67	I_{18}	5.63	I_{18}	5.50
23rd	I_{23}	5.64	I_{30}	5.49	I_{30}	5.45
24th	I_{20}	5.60	I_{20}	5.42	I_{20}	5.41
25th	I_{45}	5.43	I_{45}	5.28	I_{45}	5.32
26th	I_{37}	5.26	I_{26}	5.17	I_{42}	5.08
27th	I_{42}	5.26	I_{42}	5.17	I_{37}	5.06
28th	I_{43}	5.20	I_{37}	5.11	I_{43}	5.01
29th	I_{26}	5.13	I_{43}	5.08	I_{26}	4.97 ②
30th	I_9	4.93	I_9	4.87 ②	I_9	4.79
31st	I_{38}	4.92 ②	I_{38}	4.81	I_{38}	4.70
32nd	I_{11}	4.58	I_5	4.49	I_5	4.65
33rd	I_{13}	4.56	I_{13}	4.46	I_{33}	4.56
34th	I_{33}	4.49	I_{33}	4.45	I_6	4.47
35th	I_{12}	4.46	I_{11}	4.43	I_{11}	4.41
36th	I_{19}	4.46	I_{19}	4.38	I_{13}	4.35
37th	I_6	4.42	I_6	4.36	I_{19}	4.34
38th	I_5	4.33	I_{12}	4.34	I_{35}	4.33
39th	I_{34}	4.25	I_{25}	4.30	I_{34}	4.29
40th	I_{25}	4.17	I_{35}	4.23	I_{12}	4.28
41st	I_{35}	4.03	I_{34}	4.21	I_{25}	4.10
42nd	I_{22}	3.90 ③	I_{22}	3.95	I_{22}	3.96
43rd	I_{44}	3.54	I_{44}	3.43	I_{36}	3.54 ③
44th	I_{36}	3.17	I_{36}	3.38 ③	I_{44}	3.42
45th	I_{14}	3.17	I_{14}	3.12	I_{14}	3.11

Zone ① Critical
Zone ② Less critical
Zone ③ Noncritical

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Conclusion

In line with the development of China's accession to the WTO, the Chinese construction market has been gradually open to the outside and is becoming part of the international construction market. Contractors, particularly those from overseas, will find more business opportunities in the Chinese market. Thus, it is important for contractors to gain a proper understanding of the practice of assessing contractor competitiveness in this market. This study has formulated a list of contractor competitiveness indicators adopted in the current Chinese construction market, and KCIs are identified for different types of construction projects. The application of AHP technique and cluster analysis method in conducting data analysis has improved the reliability of the identification on the KCIs. Different KCIs should be used for assessing contractor competitiveness when different types of construction contracts are awarded.

The identification of KCIs provides valuable information for helping contractors to prepare themselves effectively when they consider competing for works in the Chinese construction market. Contractors are advised to give more attention to these key indicators by which their competitiveness is measured. The research results are also useful for project clients to consider choosing proper indicators for assessing contractors' competitiveness. While the data used in the analysis are collected from the Chinese construction industry, the findings provide useful references for further studies in comparing the KCIs used in China and those major competitiveness indicators used in other construction industries.

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