Measuring Corruption in Public Construction Projects in China

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Abstract: Corruption has been identified as the greatest obstacle to economic and social development. Public construction projects, in particular, face high corruption risk as public construction sector has been consecutively deemed as the most corrupt one. Despite considerable efforts have been undertaken to measure corruption at a nation level, few researchers focus on the measurement of corruption in construction projects. This paper develops a fuzzy measurement model for the potential corruption in public construction projects in China. Through semistructured interviews with 14 experts, and then a questionnaire survey with 188 respondents, 24 measurement items of corruption were identified and further categorized into five constructs. The fuzzy set theory was then adopted to quantify each measurement item, construct, and the overall corruption level. This model can facilitate in evaluating, revealing, and monitoring corruption in public construction projects. Although this paper focuses on measuring corruption in public construction projects in China, similar research methods can be applied in other countries around the world and thus contribute to the global body of knowledge of corruption. **DOI: 10.1061/(ASCE)EI.1943-5541.0000241.** *© 2015 American Society of Civil Engineers.*

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Introduction

Compared with developed countries, those developing countries have more serious corruption problems as they are undergoing the transition of economy and lack mature legislative and administrative system (Ofori 2000; Ling and Hoang 2010). As a typical developing country, China is unexceptional (Shan et al. 2014). The National Bureau of Corruption Prevention reveals that 15,010 persons were prosecuted for corruption in the public construction sector between 2009 and 2011, which caused an estimated loss of CNY 3 billion (approximately US $490 million; Xinhua Net 2011). Moreover, people involved in corruption not only include clerks at the bottom but also top leaders at the ministerial level or above. A notorious case is Xilai Bo, who used to be a member of the Political Bureau of the Communist Party of China Central Committee, and also the chief leader of Chongqing City (i.e., a deputy national leader of the country), was found to have grafted CNY 5 million (approximately US $0.81 million) during the construction of a public project (Xinhua Net 2013b). Another notorious case is Zhijun Liu, the former minister of Ministry of Railways (i.e., minister level), who grafted CNY 64.6 million (approximately US $10.5 million) within the construction of Chinese railway projects (Xinhua Net 2013a). Although nowadays some anticorruption measures have been put in place actively by the new leader of the country, President Jinping Xi, and that the positive effects of these measures are emerging, there is still a long way to go for Chinese people in curbing corruption (Beijing Times 2014).

Le et al. (2014b) has conducted a comprehensive literature review on corruption research in construction in the past 2 decades, and found that existing research interests of corruption mainly focused on forms of corruption in construction, impacts of corruption in construction, and anticorruption strategies, but little on the measurement of corruption in construction, which is an important aspect in addressing corruption issues. Therefore, this paper aims to develop a systematic model to measure the potential corruption in a public construction project. It is envisaged that this model can play a vital role in assessing and monitoring corruption within the Chinese public construction projects.

Literature Review

Corruption is a type of dishonest or fraudulent practice conducted by those morally depraved individuals in power, who usually misuse the public power for their private benefit (Gray and Kaufman 1998; Oxford Dictionaries 2014). This wrongdoing distorts markets and the allocation of resources, and is therefore to reduce economic efficiency and growth (Tanzi 1998; Jain 2001; Marquette 2001). Moreover, corruption can give rise to a dirty image of the country and degrade public trust (Ika et al. 2012). With respect to the construction industry, there has even been an increase of corruption within the sector in recent years (Alutu 2007; Ameh and Odusami 2010; Sohail and Cavill 2008; de Jong et al. 2009;

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Bowen et al. 2012; Gunduz and Önder 2013; Le et al. 2014b). In particular, the public construction sector has been consecutively deemed as the most corrupt sector according to the Bribe Payers Index published by Transparency International (1999, 2002, 2006, 2008, 2011). The negative impacts of corruption on the construction sector include unfair resource allocation, waste of public money, low quality of construction work, and foremost, the undermining of free competition in the business (Sohail and Cavill 2008; Tabish and Jha 2011; Le et al. 2014a).

Measurement of corruption is necessary to achieve progress towards greater integrity, transparency, and accountability in corruption-free performance (Andersson and Heywood 2009; Goel and Nelson 2011; Foster et al. 2012; León et al. 2013). Only by understanding how much corruption, and in what areas, can effective anticorruption strategies be formulated and then implemented (Sampford et al. 2006). Kaufmann et al. (1999) therefore creating an aggregate measure of corruption combining three elements of governance, namely (1) probity, (2) bureaucratic quality, and (3) rule of law. Hall and Yago (2000) developed an index of opacity, which is the opposite of transparency. Additionally, extensive efforts have been devoted to the measurement of corruption at the country level by many international organizations, such as Business International Corporation, the Political Risk Services Group, World Economic Forum, Political and Economic Risk Consultancy, Transparency International, and the World Bank (Mauro 1995; Lancaster and Montinola 1997; Lambsdorff 1998; Tanzi and Davoodi 1998; Jain 2001; Svensson 2005). However, rare literature was found to focus on the measurement of corruption in the construction sector. Thus, this paper attempts to bridge this knowledge gap by developing a systematic evaluation model of corruption in construction projects.

Data Collection

Data source is critical for measuring corruption, which includes perception indicators, judicial system reports, and indirect and outcome indicators (e.g., objective indictors covering financial flows and sector outcomes; Kenny 2009). Data from judicial system reports can improve the precision of measurement and disclose more significant details of corruption (Della Porta 2001), but those judicial reports are rarely available by the public (Han 2011). Although indirect and outcome indicators can be widely available, the reliability of results derived from these data may be compromised because factors other than corruption might contribute to the final evaluation (Ko and Samajdar 2010). In the research reported in this paper, perception indicators were used to solicit perception-based data to measure corruption in public construction projects. This data collection method has also been widely used for the measurement of corruption at a country level (Mauro 1995; Lancaster and Montinola 1997; Lambsdorff 1998; Andersson and Heywood 2009; Goel and Nelson 2011; Foster et al. 2012). Although subjective data collected by such approach can only reflect vague and generic perceptions of corruption, rather than specific objective realities and thus sometimes unreliable (Golden and Picci 2001; Duncan 2006; Seligson 2006), perceptions of corruption based on respondents' actual experiences are, in most cases, the best and the only information the researchers can obtain as corruption is usually carried out clandestinely and leaves no paper trail (Jain 2001). A series of semistructured interviews and a questionnaire survey were employed sequentially in the research reported in this paper as tools for data collection, because such a combination of methods has been advocated and can overcome inherent limitations of a single method (Zhao et al. 2013a).

Semistructured Interviews

To identify measurement items of corruption, semistructured interviews were first conducted between July 2013 and August 2013, with 14 industrial experts and academics. Table 1 shows the backgrounds of the interviewees. Apparently, most of interviewees have sufficient working experience (more than 10 years) and hold senior positions in their organizations. Diversified professional backgrounds and geographic locations of interviewees also help increase the heterogeneity of the interviewee panel, and thus improve the validity of interviews.

As Tabish and Jha (2011) has already gathered a comprehensive list of 61 measurement items of corruption in Indian public construction projects, this list will be adopted and serve as the basis for the development of measurement items specifically for construction projects in China. Interviewees were requested to evaluate the applicability of each item from Tabish and Jha (2011) to the

Table 1. Backgrounds of Interviewees

Number	Employer	Position	Experience (years)	Largest project ever managed/consulted (millions of U.S. dollars)	Geographic locations[a]
A	Government	Director	20	363	Eastern China
B	Government	Deputy director	16	308	Central China
C	Client	Project manager	19	363	Western China
D	Client	Project manager	17	308	Eastern China
E	Client	Director	13	167	Northeastern China
F	Contractor	General manager	25	363	Eastern China
G	Contractor	Project manager	20	122	Western China
H	Contractor	Director	15	85	Central China
I	Consultant	General manager	20	363	Eastern China
J	Consultant	Project manager	16	122	Western China
K	Consultant	Project manager	15	85	Northeastern China
L	Academic	Professor	22	197	Central China
M	Academic	Professor	17	73	Western China
N	Academic	Associate Professor	13	363	Northeastern China

[a]Geographic locations are divided into eastern China with gross domestic product (GDP) per capita about US $8,600, central China with GDP per capita about US $4,700, western China with GDP per capita about US $4,400, and northeastern China with GDP per capita about US $6,600, according to NBSC (2012).

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public construction sector of China, by using a five-point rating system [(1) very inapplicable, (2) inapplicable, (3) medium, (4) applicable, and (5) very applicable]. Interviewees were also encouraged to supplement other measurement items that they had in mind but had not been included in Tabish and Jha (2011) framework. The mean score of each measurement item was calculated, and a threshold of 2.5 points was established as a cutoff criterion as recommended by Hsueh et al. (2009).

Based on the interview results, as shown in Table 2, 19 items from Tabish and Jha (2011) framework received evaluation scores above 2.5 points, suggesting that their applicability in the Chinese public construction sector were confirmed. Due to the objective difference between the construction sectors of India and China, other items from Tabish and Jha (2011) framework, for example, "the reimbursement of service tax, excise duty, etc. is not done after obtaining the actual proof of depositing the same," and "the recoveries for statutory taxes/duties not made before releasing the payment," were regarded as inapplicable to measure the corruption in the context of China (with applicability score lower than 2.5 points), and thus were excluded from the list of measurement items. To verify if there is significant difference among the interviewees of different backgrounds (i.e., employer, experience, and geographic locations), the Kruskal–Walis test was conducted with the aid of *SPSS 17.0*. According to Siegel and Castellan (1988), the significant difference is proved when the asymptotic significance value is lower than 0.05. The testing results in Table 2 show that all the asymptotic significance values are greater than 0.05, which indicates that no significant differences exist among the interviewees of different backgrounds.

Additionally, a complement of five new measurement items was recommended by the interviewees according to their own experience, as shown in Table 3. Therefore, a total of 24 measurement items of corruption were finalized through interviews.

Questionnaire Survey

As a systematic data collection method, the questionnaire survey technique has been widely used to collect professional views in construction management research (such as Deng et al. 2014; Hwang et al. 2014; Le et al. 2014a; Zhao et al. 2013a). Thus, after the semistructured interviews, a questionnaire survey was conducted to obtain the perception-based data of the measurement items of corruption from two perspectives, namely (1) probability (i.e., the possibility of occurrence of each measurement item), and (2) severity (i.e., the impact of consequence of each measurement item), using a five-point rating scale [(1) very low, (2) low, (3) medium, (4) high, and (5) very high]. The questionnaire was disseminated through three channels between September 2013 and October 2013, as follows: (1) an online version of the questionnaire was developed and disseminated to experts from government agencies, research institutes, and enterprises involved in public construction projects in China; (2) hard copies of the questionnaire were distributed in a one-to-one interview way to some participants of an industrial forum held in Shanghai, who are required to have experience in Chinese public construction projects; and (3) field surveys were conducted in three public construction projects in Shanghai, Jinan (the capital city of Shandong Province), and Zhengzhou (the capital city of Henan Province). Moreover, two particular measures were taken to ensure the reliability of the survey feedbacks, as follows: (1) the questionnaire was administered in an anonymous way, and (2) the respondents were asked to evaluate the measurement items of corruption merely based on their knowledge to the industry rather than the projects they were engaging in. The three survey approaches adopted in the research reported in this paper are expected to enhance the validity of the survey results. Finally, 188 valid replies were received. Among them, 87 replies were collected from the online survey, 20 from the industrial forum, and 81 from the field surveys.

Table 2. Measurement Items Refined by the Interviewees

Code[a]	Measurement item	Applicability evaluation	Asymptotic significance of Kruskal–Wallis test: Employer	Experience[b]	Geographic locations
MI1	Administrative approval and financial sanction not taken to execute the work	2.79	0.274	0.432	0.358
MI2	Provisions are not as per laid down yardstick	3.86	0.352	0.423	0.329
MI3	Work is not executed for the same purpose for which the sanction was accorded	2.93	0.462	0.586	0.497
MI4	Consultant is not appointed after proper publicity and open competition	3.64	0.516	0.607	0.509
MI5	Criteria adopted in prequalification of consultant are restrictive and benefit only few consultants	3.43	0.687	0.723	0.648
MI6	Selection of consultant not done by appropriate authority	3.57	0.414	0.580	0.426
MI7	Adequate and wide publicity is not given to tender	2.71	0.438	0.452	0.379
MI8	Adequate time for submission of tender/offer not given	2.64	0.649	0.765	0.721
MI9	Prequalification criteria for selection of contractor are stringent	3.00	0.649	0.681	0.752
MI10	Evaluation of tenders is not done exactly as per the notified criteria	2.57	0.350	0.308	0.239
MI11	Negotiation on tender not done as per laid down guidelines	3.00	0.251	0.235	0.189
MI12	Conditions/specifications are relaxed in favor of contractor to whom the work is being awarded	3.50	0.421	0.462	0.473
MI13	Work order/supply order is not placed within justified rates	2.71	0.498	0.502	0.535
MI14	Work is executed without the availability of funds for the said purpose	3.93	0.547	0.640	0.508
MI15	Work is not executed as per original sanction accorded	3.93	0.686	0.703	0.604
MI16	Compliance with conditions regarding obtaining licenses, insurance policies, and deployment of technical staff not being performed by contractor	3.71	0.579	0.534	0.406
MI17	Proper record of hindrances is not being maintained from the beginning	2.93	0.663	0.650	0.631
MI18	Deviations, especially in abnormally high rated and high-value items, are not properly monitored and verified	3.29	0.428	0.460	0.325
MI19	Escalation clause is not applied correctly for admissible payment	3.57	0.492	0.431	0.463

[a]MI = measurement item.
[b]Experience is categorized into two groups in accordance with the following criteria: (1) below 20 years, and (2) above 20 years.

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Table 3. Measurement Items Supplemented by the Interviewees

Code[a]	Measurement item	Interviewee														Applicability evaluation
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	
MI20	Large project should have called for bids is split into several small projects and contracted without bidding	—	—	—	[b]	[b]	[b]	—	[b]	—	[b]	[b]	[b]	—	[b]	3.40
MI21	Contractors provide false certificates in bidding	[b]	[b]	[b]	—	—	—	[b]	[b]	—	[b]	—	[b]	[b]	—	3.96
MI22	Confidential information of bidding is disclosed to a specific bidder	[b]	—	—	[b]	—	—	[b]	—	[b]	—	[b]	[b]	—	[b]	3.76
MI23	Substitution of unqualified materials in construction	[b]	[b]	—	[b]	[b]	—	—	—	[b]	[b]	[b]	[b]	[b]	[b]	3.54
MI24	Site supervisor neglects his duties for taking bribe from contractor	—	[b]	[b]	[b]	[b]	—	—	—	[b]	[b]	—	[b]	[b]	[b]	3.91

[a]MI = measurement item.
[b]The item was proposed and supplemented by the interviewee.

Table 4 shows profile of respondents of the questionnaire survey. The respondents are from diversified organizations (i.e., government, client, contractor, consultant, designer, and academic) involved in public construction projects in China. More than 70% of them had at least 6 years of experience in this sector and held middle managerial positions or above in their organizations. In addition, the respondents were selected from different geographic locations of China in order to provide a more general situation of corruption in the public construction sector across the country.

Data Analysis

To check the reliability of the data collected from the questionnaire survey, Cronbach's coefficient alpha was tested with the aid of *SPSS 17.0*, as suggested by Netemeyer et al. (2003). The testing result revealed a Cronbach's alpha value of 0.902, which indicates a high level of internal consistency among the respondents (Netemeyer et al. 2003).

Table 5 shows the evaluations of 24 measurement items. The top five measurement items in terms of probability are (1) MI17 (3.71 points), (2) MI12 (3.54 points), (3) MI16 (3.52 points), (4) MI15 (3.45 points), and (5) MI4 (3.43 points). The top five measurement items in terms of severity are (1) MI23 (4.06 points), (2) MI24 (4.00 points), (3) MI17 (3.80 points), (4) MI22 (3.73 points), and (5) MI21 (3.70 points). The Kruskal–Wallis test was also performed with the aid of *SPSS 17.0* to check if there is significant difference among the respondents of different professional backgrounds (i.e., employer, position, experience, and geographic location). Given all the asymptotic significance values are greater than 0.05, there is no such significant difference among the respondents (Siegel and Castellan 1988). Therefore, the data are appropriate to be further analyzed.

Table 4. Profile of Respondents

Personal attributes	Categories	Number of respondents	Percentage
Employer	Government	20	10.6
	Client	43	22.9
	Contractor	43	22.9
	Consultant	46	24.5
	Designer	26	13.8
	Academic	10	5.3
Position	Top managerial level, e.g., director, general manager, or professor	49	26.1
	Middle managerial level, e.g., project manager	88	46.8
	Professional, e.g., engineer or quantity surveyor	51	27.1
Experience (years)	>20	24	12.8
	11–20	40	21.3
	6–10	76	40.4
	<5	48	25.5
Geographic locations[a]	Eastern China	63	33.5
	Central China	55	29.2
	Western China	37	19.7
	Northeastern China	33	17.6

[a]Geographic locations are divided into eastern China with GDP per capita about US $8,600, central China with GDP per capita about US $4,700, western China with GDP per capita about US $4,400, and northeastern China with GDP per capita about US $6,600, according to NBSC (2012).

Normally, an evaluation model is developed from a hierarchical framework (Xu et al. 2010). Therefore, to hierarchize the framework of measurement items of corruption, factor analysis was conducted utilizing *SPSS 17.0*. As recommended by Chan et al. 2010)) and Xia and Chan (2012), principal component analysis was conducted to identify the underlying constructs of measurement items for its simplicity and distinctive capacity of data reduction. Assuming that there are correlations among various constructs of measurement items, factor extraction with promax rotation was conducted as suggested by Conway and Huffcutt (2003) and Zhao et al. (2014a). Meanwhile, the appropriateness of using factor analysis was evaluated by using Kaiser–Meyer–Olkin (KMO) and Bartlett's test of sphericity (Dziuban and Shirkey 1974; Norusis 2008).

Table 6 shows the results of factor analysis of measurement items. Five constructs, namely (1) immorality, (2) unfairness, (3) opacity, (4) procedural violation, and (5) contractual violation, which encapsulate 24 measurement items, were generated. This result is in line with the findings of Tabish and Jha (2011). The KMO value is 0.863, which is higher than the threshold of 0.5 (Norusis 2008). The total variance explained is 61.622%, higher than the common threshold of 60% adopted in social science research (Hair et al. 2010). Bartlett's test of sphericity produced an approximate chi-squared value $x^2 = 1{,}308.051$ [degrees of freedom $(\mathrm{DOF}) = 276$, $p = 0.000$], indicating the high correlations among measurement items (Dziuban and Shirkey 1974). Moreover, the correlation matrix as indicated in Table 7 shows that the five constructs are not highly correlated with each other at 5% significance level (all of them are insignificantly correlated with each other), suggesting no multiplier effect among them. Thus, all the statistical parameters were acceptable to conduct factor analysis. Hair et al. (2010) stated that the loading of each measurement item on its corresponding construct should not be lower than 0.5. Therefore, MI6, MI8, MI13, MI 14, and MI17 were excluded from the final list of measurement items. The remaining measurement items were recoded to facilitate further research action as shown in Table 6.

Table 5. Evaluations of the Measurement Items for Corruption

Code[a]	Probability					Severity				
		Asymptotic significance of Kruskal–Wallis test					Asymptotic significance of Kruskal–Wallis test			
	Mean	Employer	Position	Experience	Geographic location	Mean	Employer	Position	Experience	Geographic location
MI1	2.63	0.121	0.236	0.275	0.283	3.30	0.202	0.326	0.378	0.364
MI2	3.20	0.629	0.534	0.426	0.479	3.50	0.215	0.369	0.475	0.382
MI3	2.47	0.058	0.102	0.162	0.109	3.31	0.213	0.208	0.253	0.231
MI4	3.43	0.438	0.472	0.374	0.301	3.26	0.668	0.621	0.643	0.665
MI5	3.14	0.692	0.613	0.624	0.635	3.14	0.404	0.467	0.478	0.589
MI6	3.06	0.263	0.241	0.252	0.363	3.00	0.261	0.263	0.274	0.385
MI7	2.74	0.788	0.739	0.728	0.717	3.05	0.418	0.465	0.454	0.443
MI8	2.70	0.259	0.278	0.287	0.296	3.06	0.231	0.253	0.275	0.297
MI9	3.21	0.083	0.105	0.127	0.149	3.34	0.124	0.126	0.148	0.160
MI10	2.62	0.156	0.178	0.190	0.212	3.37	0.227	0.249	0.261	0.283
MI11	2.28	0.265	0.287	0.309	0.331	3.50	0.372	0.394	0.416	0.438
MI12	3.54	0.276	0.298	0.310	0.332	2.92	0.774	0.796	0.818	0.830
MI13	3.16	0.301	0.323	0.345	0.367	3.51	0.223	0.245	0.267	0.289
MI14	2.79	0.073	0.095	0.117	0.139	3.51	0.219	0.231	0.253	0.275
MI15	3.45	0.423	0.467	0.489	0.445	3.69	0.150	0.172	0.194	0.216
MI16	3.52	0.299	0.311	0.347	0.369	3.61	0.201	0.223	0.245	0.267
MI17	3.71	0.511	0.535	0.557	0.579	3.80	0.211	0.236	0.258	0.270
MI18	3.06	0.272	0.294	0.316	0.338	3.60	0.337	0.359	0.371	0.393
MI19	3.08	0.552	0.574	0.596	0.618	3.28	0.362	0.384	0.406	0.428
MI20	2.79	0.270	0.292	0.314	0.336	3.51	0.210	0.232	0.254	0.276
MI21	3.04	0.557	0.579	0.591	0.613	3.70	0.193	0.215	0.237	0.259
MI22	3.05	0.198	0.210	0.232	0.257	3.73	0.293	0.315	0.337	0.359
MI23	3.01	0.252	0.274	0.296	0.318	4.06	0.189	0.201	0.223	0.245
MI24	3.23	0.213	0.235	0.257	0.279	4.00	0.293	0.315	0.327	0.349

[a]MI = measurement item.

Table 6. Factor Analysis Results and Weighting Calculation

Construct	Previous code[a]	New code[a]	Factor loading	Variance explained	Weightings	
					Probability	Severity
Immorality				33.679%	0.28	0.33
	MI14	—	0.474		—	—
	MI15	MI1.1	0.727		0.22	0.20
	MI18	MI1.2	0.696		0.19	0.19
	MI21	MI1.3	0.673		0.19	0.19
	MI23	MI1.4	0.735		0.19	0.21
	MI24	MI1.5	0.750		0.21	0.21
Unfairness				9.718%	0.29	0.24
	MI4	MI2.1	0.797		0.21	0.20
	MI5	MI2.2	0.849		0.19	0.19
	MI6	—	0.451		—	—
	MI9	MI2.3	0.708		0.20	0.20
	MI12	MI2.4	0.636		0.22	0.18
	MI22	MI2.5	0.654		0.18	0.23
Opacity				6.644%	0.18	0.19
	MI7	MI3.1	0.720		0.26	0.23
	MI8	—	0.482		—	—
	MI10	MI3.2	0.752		0.25	0.25
	MI11	MI3.3	0.759		0.22	0.26
	MI20	MI3.4	0.616		0.27	0.26
Procedural violation				6.300%	0.14	0.14
	MI1	MI4.1	0.742		0.32	0.33
	MI2	MI4.2	0.707		0.38	0.34
	MI3	MI4.3	0.640		0.30	0.33
	MI17	—	0.440		—	—
Contractual violation				5.281%	0.11	0.10
	MI13	—	0.443		—	—
	MI16	MI5.1	0.573		0.53	0.52
	MI19	MI5.2	0.746		0.47	0.48

Note: Cumulative variance explained 61.622%; Kaiser–Meyer–Olkin measure of sampling adequacy = 0.863; and significance of Bartlett's test of sphericity = 1,308.051 ($p = 0.000$).
[a]MI = measurement item.

Based on the data collected from the questionnaire survey, the weightings of each measurement item and construct were calculated. The weighting of probability for the mth measurement item under construct i (W_{pim}) can be computed by

$$W_{\mathrm{pim}} = MS_{\mathrm{pim}} / \sum_{m=1}^{n} MS_{\mathrm{pim}} \tag{1}$$

where MS_{pim} = mean value of the measurement item m; and n = number of measurement items under the construct i.

The probability weighting of the construct i (W_{pi}) can be computed by

$$W_{pi} = TMS_{pi} / \sum_{i=1}^{5} TMS_{pi} \tag{2}$$

where TMS_{pi} = total mean values of measurement items under the construct i.

Table 7. Correlation Matrix among the Five Constructs of Measurement Items of Corruption

Construct	Immorality	Unfairness	Opacity	Procedural violation	Contractual violation
Immorality	1	—	—	—	—
Unfairness	0.441	1	—	—	—
Opacity	0.303	0.390	1	—	—
Procedural violation	0.464	0.351	0.190	1	—
Contractual violation	0.263	0.336	0.201	0.315	1

Note: No correlations were significant at either the 5% or the 1% levels (two-tailed).

Similarly, the weighting of severity for mth measurement item under the corresponding construct i (W_{sim}), and the weighting of the construct i (W_{si}), can be computed by the same approach. Table 6 shows the weightings of all the measurement items and its related constructs.

Model Development: Fuzzy Measurement

Considering that the perceptions of probability and severity levels of measurement items by respondents are typically characterized by subjectivity and uncertainty, and thus are fuzzy by nature, the fuzzy set theory was employed to develop the measuring model in the research reported in this paper. Fuzzy set theory is a branch of modern mathematics that was formulated by Zadeh (1965) to model vagueness intrinsic in human cognitive process. On the basis of linguistic variables and membership functions with varying grades, fuzzy set theory allows for the development of strong and significant instruments for the measurement of ambiguities, and provides the opportunity to represent meaningfully ambiguous concepts expressed in the natural language (Zimmermann 2001; Gunduz et al. 2013). This approach is quite appropriate to tackle the complex problems due to the imprecise, uncertain, or unreliable information that characterize the real-world systems (Baloi and Price 2003; Chan et al. 2009; Xia et al. 2011).

Fuzzy set theory deals with a set of objects characterized by a membership function that assigns to each object a grade of membership ranging between 0 (no membership) and 1 (full membership; Shaheen et al. 2007). Theoretically, membership functions can take various shapes (Lorterapong and Moselhi 1996). However, in modeling real-life problems, linear approximation such as triangular fuzzy number (TFN) is frequently used (Chen and Hwang 1992; Zhao et al. 2013b). Additionally, the precision in the shape of the membership functions is unimportant due to the quantitative nature of the problems with vague predicates, and the fuzzy numbers with simpler membership function shapes tend to have more intuitive and more natural interpretation (Nieto-Morote and Ruz-Vila 2011; Zhao et al. 2013b). Therefore, the research reported in this paper utilizes the TFN to quantify the qualitative data collected through the questionnaire survey.

The input data of the proposed model are the values of linguistic variables. Although linguistic variables have lower quality of exactness than numerical variables whose values are numbers, they are more meaningful (Hadipriono 1988). Two linguistic variables were defined for each measurement item of corruption, namely (1) probability, and (2) severity. A five-point Likert scale [(1) very low, (2) low, (3) medium, (4) high, and (5) very high] was adopted to assign the linguistic variables as recommended by Zhao et al. (2013b). This rating system is easy for users to understand these linguistic terms and evaluate the measurement items of corruption.

The values of linguistic variables were then transformed into triangular fuzzy numbers. Each fuzzy set has to overlap its neighboring sets to certain extent. While there is no precise algorithm for determining the minimum or maximum degree of overlap, in most cases, the overlap for triangle-to-triangle fuzzy regions averages between 25 and 50% of the fuzzy set base (Cox 1999; Li et al. 2006). Cox (1999) further stated that a high degree of overlap can ensure any small changes of the rating system be detected and handled immediately. Therefore, the research reported in this paper adopts 50% as the degree to which each triangular fuzzy region overlaps its neighboring region. Fig. 1 shows the membership functions of various linguistic values.

The TFN of mth measurement item under construct i in the assessment of probability, i.e., $\tilde{C}_{\text{pim}}$, can be computed using

$$\begin{aligned}\tilde{C}_{\text{pim}} &= 1/k \times \sum_{j=1}^{k} \tilde{C}_{\text{pim}j} \\ &= 1/k \times \left(\sum_{j=1}^{k} l_{\text{pim}j1}, \sum_{j=1}^{k} l_{\text{pim}j2}, \sum_{j=1}^{k} l_{\text{pim}j3} \right)\end{aligned} \tag{3}$$

where k = number of individuals who assess the measurement items; and $l_{\text{pim}j1}$, $l_{\text{pim}j2}$, and $l_{\text{pim}j3}$ = lower bound, strongest membership degree, and upper bound of $\tilde{C}_{\text{pim}j}$, respectively.

Then the TFN of construct i in the assessment of probability, i.e., $\tilde{C}_{pi}$, can be computed using

$$\tilde{C}_{pi} = \sum_{m=1}^{n} \tilde{C}_{\text{pim}} \times W_{\text{pim}} \tag{4}$$

where n = number of measurement items under construct i; and W_{pim} = weighting of mth measurement item under construct i in the assessment of probability (available in Table 6).

The TFN of corruption in the assessment of probability, namely, $\tilde{C}_p$, can be computed using

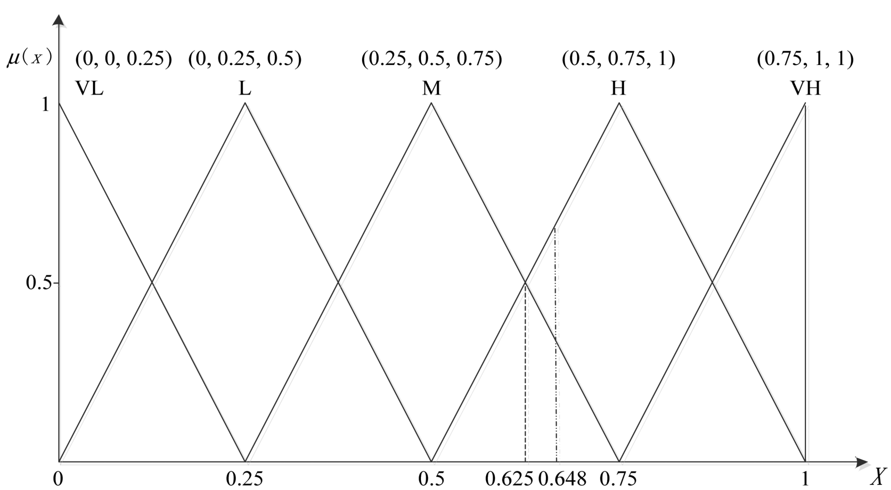

Fig. 1. Membership functions of linguistic values

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$$\tilde{C}_p = (p_1, p_2, p_3) = \sum_{i=1}^{5} \tilde{C}_{pi} \times W_{pi} \quad (5)$$

where W_{pi} = weighting of construct i in the assessment of probability and are available in Table 5; and p_1, p_2, and p_3 are lower bound, strongest membership degree, and upper bound of $\tilde{C}_p$, respectively.

Similarly, the TFN of corruption in the assessment of severity, namely, $\tilde{C}_s = (s_1, s_2, s_3)$ can be calculated using the same approach. In this case, s_1, s_2, and s_3 are lower bound, strongest membership degree, and upper bound of $\tilde{C}_s$, respectively.

Defuzzification is the process of determining a crisp value that adequately represents the fuzzy number (Georgy et al. 2005). There are several defuzzification methods such as center of gravity (COG; calculation of geometric center of the fuzzy outputs), mean of maxima (MOM; mean of the highest membership values of the fuzzy outputs), and bisection (crisp value that divides the area of the membership function of the fuzzy output into two equally sized sections), with each one having its strengths and weakness (Filev and Yager 1994; Lam et al. 2010; Kishore et al. 2011). As the research reported in this paper uses the TFN, the COG is easy to compute and the defuzzified value tends to be move smoothly around the output fuzzy region. Thus the evaluation of corruption in terms of probability (C_p) and severity (C_s) can be calculated using

$$C_p = 1/3 \times \sum_{t=1}^{3} p_t \quad (6)$$

$$C_s = 1/3 \times \sum_{t=1}^{3} s_t \quad (7)$$

Finally, the corruption in a public construction project can be calculated as per the recommendation of Xu et al. (2010)

$$C = \sqrt{C_p \times C_s} \quad (8)$$

The potential corruption in a public construction project, i.e., C, is a crisp value in the interval [0,1] that falls into the regions of two adjacent linguistic terms. The corruption can be interpreted by the linguistic term that has a higher membership value (Zhao et al. 2013b).

Illustrative Case

In December 2013, a real public construction project in Jinan (the capital city of Shandong Province, eastern China) was contacted to assess its potential corruption using the proposed model. The project was selected for the following two reasons: (1) the project is a typical public project having a high estimated cost (CNY 23 billion, approximately US $3.74 billion), which attracts the intensive attention from the local society; and (2) the writers used to provide consultancy service for this project, which can help obtain data of high reliability considering the topic of current study is so sensitive. The input data of the model were collected from five professionals of a consultancy company who were employed to provide the auditing service in this project. To ensure the reliability of the data, an anonymous and self-explanatory questionnaire composed of 19 measurement items was distributed to the five professionals, and the completed questionnaires were collected using a lockbox. The calculation of potential corruption in this project is illustrated as described next.

First, the TFN of each measurement item in the assessment of probability was calculated using Eq. (3). For instance, MI1.3, contractors provide false certificates in bidding, obtained the linguistic values of high, very high, high, high, and very high from the five respondents. Fig. 1 suggests that the TFNs of high and very high are (0.50, 0.75, 1.00) and (0.75, 1.00, 1.00), respectively. Therefore, $\tilde{C}_{p13}$ was calculated

$$\begin{aligned}\tilde{C}_{p13} = 1/5 \times [&(0.50, 0.75, 1.00) + (0.75, 1.00, 1.00) \\ &+ (0.50, 0.75, 1.00) + (0.50, 0.75, 1.00) \\ &+ (0.75, 1.00, 1.00)] = (0.60, 0.85, 1.00)\end{aligned} \quad (9)$$

Then using the TFNs of measurement items as input in Eq. (4) the TFNs of various constructs was obtained. Finally, the TFNs of various constructs were inputted in Eq. (5) and the TFNs of corruption in terms of probability of this project were obtained. By using the same approach, the TFNs of each measurement item, each construct, as well as the corruption in terms of severity was calculated. Table 8 shows all the values of $\tilde{C}_{\text{pim}}$, $\tilde{C}_{pi}$, $\tilde{C}_p$, $\tilde{C}_{\text{sim}}$, $\tilde{C}_{si}$, and $\tilde{C}_s$.

Thus, C_p and C_s were computed using Eqs. (6) and (7)

$$C_p = 1/3 \times (0.423 + 0.663 + 0.861) = 0.649 \quad (10)$$

$$C_s = 1/3 \times (0.402 + 0.651 + 0.891) = 0.648 \quad (11)$$

Potential corruption of this project was computed upon Eq. (8)

$$C = \sqrt{0.649 \times 0.648} = 0.648 \quad (12)$$

According to Fig. 1, the value of C (0.648) fell into the two adjacent regions of (1) medium, and (2) high. The linguistic value of high has a higher membership value than that of medium when the X value is 0.648. Therefore, the potential corruption level of this project is high. Additionally, values of various constructs, such as immorality, unfairness, opacity, procedural violation, and contractual violation, were calculated using the same approach according to Eqs. (6)–(8), and the calculating results are as shown in Fig. 2. The results show that the values of immorality and contractual violation are 0.744 and 0.705, which are greater than 0.625. Therefore, it can be concluded that the project has high potential corruption levels in terms of immorality and contractual violation.

Unexpectedly, the writers were informed in February 2014 (i.e., 2 months later than the model application) that corruption was found in this project. Soon afterwards, the writers made an additional telephone interview with one professional who participated in the assessment of the project, and were further informed that one staff of the client and another staff from the site supervisor had been secretly investigated by the prosecutor since June 2013, and that they were detained with their corrupt practices confirmed in February 2014. The professional also mentioned the following main corrupt practices that have been verified by the prosecutor: (1) fake bidding was conducted by the client and its designated contractor, (2) some frontline workers hired by the contractor had no practicing certifications thus resulted in low construction quality, and (3) site supervision engineers took bribe from the contractor and loosened due supervision. These corrupt acts are exactly reflected in measurement items (e.g., MI16, MI21, and MI24) under the construct of immorality and contractual violation in the proposed model. Therefore, the results obtained from the proposed model can be regarded as reliable.

Limitation of the Paper

Although increasing efforts have been invested in recent years to corruption research, few researchers except for Tabish and Jha

Table 8. Illustrative Example of the Model Application

	Probability[b]					Severity[b]				
Measurement item[a]	C_{pim}	W_{pim}	$\tilde{C}_{pi}$	W_{pi}	$\tilde{C}_p$	$\tilde{C}_{\text{sim}}$	W_{sim}	$\tilde{C}_{si}$	W_{si}	$\tilde{C}_s$
Immorality	—	—	(0.57, 0.80, 0.96)	0.28	(0.160, 0.224, 0.269)	—	—	(0.46, 0.71, 0.95)	0.33	(0.152, 0.234, 0.314)
MI1.1	(0.65, 0.90, 1.00)	0.22	—	—	—	(0.55, 0.80, 1.00)	0.20	—	—	—
MI1.2	(0.50, 0.75, 0.95)	0.19	—	—	—	(0.45, 0.70, 0.95)	0.19	—	—	—
MI1.3	(0.60, 0.85, 1.00)	0.19	—	—	—	(0.40, 0.65, 0.90)	0.19	—	—	—
MI1.4	(0.55, 0.80, 0.95)	0.19	—	—	—	(0.45, 0.70, 0.95)	0.21	—	—	—
MI1.5	(0.55, 0.70, 0.90)	0.21	—	—	—	(0.45, 0.70, 0.95)	0.21	—	—	—
Unfairness	—	—	(0.39, 0.64, 0.86)	0.29	(0.113, 0.186, 0.249)	—	—	(0.31, 0.56, 0.81)	0.24	(0.074, 0.134, 0.194)
MI2.1	(0.40, 0.65, 0.85)	0.21	—	—	—	(0.25, 0.50, 0.75)	0.20	—	—	—
MI2.2	(0.40, 0.65, 0.85)	0.19	—	—	—	(0.20, 0.45, 0.70)	0.19	—	—	—
MI2.3	(0.45, 0.70, 0.95)	0.20	—	—	—	(0.40, 0.65, 0.90)	0.20	—	—	—
MI2.4	(0.45, 0.70, 0.90)	0.22	—	—	—	(0.20, 0.45, 0.70)	0.18	—	—	—
MI2.5	(0.25, 0.50, 0.75)	0.18	—	—	—	(0.45, 0.70, 0.95)	0.23	—	—	—
Opacity	—	—	(0.23, 0.47, 0.71)	0.18	(0.041, 0.085, 0.128)	—	—	(0.41, 0.66, 0.87)	0.19	(0.077, 0.124, 0.164)
MI3.1	(0.20, 0.45, 0.70)	0.26	—	—	—	(0.25, 0.50, 0.75)	0.23	—	—	—
MI3.2	(0.25, 0.50, 0.75)	0.25	—	—	—	(0.40, 0.65, 0.90)	0.25	—	—	—
MI3.3	(0.10, 0.30, 0.55)	0.22	—	—	—	(0.45, 0.70, 0.90)	0.26	—	—	—
MI3.4	(0.35, 0.60, 0.80)	0.27	—	—	—	(0.50, 0.75, 0.90)	0.26	—	—	—
Procedural violation	—	—	(0.38, 0.60, 0.81)	0.14	(0.053, 0.084, 0.113)	—	—	(0.40, 0.65, 0.90)	0.14	(0.056, 0.091, 0.126)
MI4.1	(0.35, 0.55, 0.75)	0.32	—	—	—	(0.45, 0.70, 0.95)	0.33	—	—	—
MI4.2	(0.40, 0.60, 0.80)	0.38	—	—	—	(0.50, 0.75, 1.00)	0.34	—	—	—
MI4.3	(0.40, 0.65, 0.90)	0.30	—	—	—	(0.25, 0.50, 0.75)	0.33	—	—	—
Contractual violation	—	—	(0.51, 0.76, 0.93)	0.11	(0.056, 0.084, 0.102)	—	—	(0.43, 0.68, 0.93)	0.10	(0.043, 0.068, 0.093)
MI5.1	(0.60, 0.85, 1.00)	0.53	—	—	—	(0.50, 0.75, 1.00)	0.52	—	—	—
MI5.2	(0.40, 0.65, 0.85)	0.47	—	—	—	(0.35, 0.60, 0.85)	0.48	—	—	—
Total	—	—	—	1	(0.423, 0.663, 0.861)	—	—	—	1	(0.402, 0.651, 0.891)

[a]MI = measurement item.
[b]$\tilde{C}_p$ = triangular fuzzy number of corruption in the assessment of probability; $\tilde{C}_{pi}$ = triangular fuzzy number of construct i in the assessment of probability; C_{pim} = triangular fuzzy number of mth measurement item under construct i in the assessment of probability; $\tilde{C}_s$ = triangular fuzzy number of corruption in the assessment of severity. $\tilde{C}_{si}$ = triangular fuzzy number of construct i in the assessment of severity; $\tilde{C}_{\text{sim}}$ = triangular fuzzy number of mth measurement item under construct i in the assessment of severity; W_{pi} = weighting of construct i in the assessment of probability; W_{pim} = weighting of mth measurement item under construct i in the assessment of probability; W_{si} = weighting of construct i in the assessment of severity; and W_{sim} = weighting of mth measurement item under construct i in the assessment of severity.

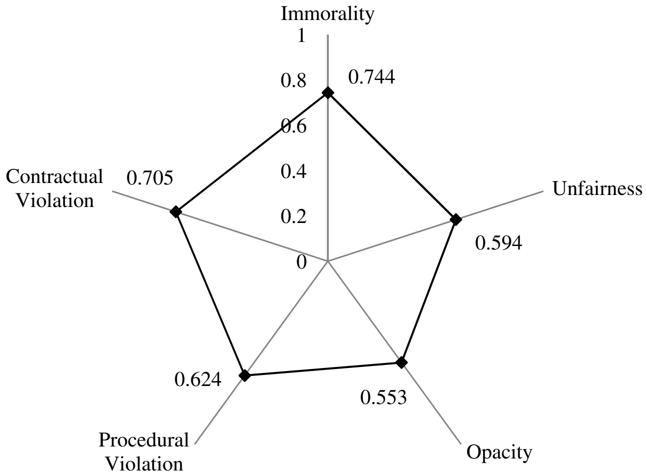

Fig. 2. Values of various constructs of the illustrative case

(2011) systematically investigated the framework of measurement items for corruption in the construction sector. That is why the framework of Tabish and Jha (2011) was selected as the grounding to establish the corresponding framework in the context of China. While a series of semistructured interviews have been conducted to help improve the framework, there is definitely room for the framework to be perfected through subsequent research input. This is the limitation of the research reported in this paper.

Conclusions and Recommendations

It is necessary to measure the potential corruption in a public construction project because such assessment can proactively help reveal the corruption vulnerabilities in the project and thus facilitate in developing related prevention measures. This paper develops a systematic model to measure corruption in public construction projects in China. Measurement items of corruption were identified and consolidated, through semistructured interviews with 14 industrial experts and academics. Data collected through a questionnaire survey with 188 experienced respondents were utilized to examine the underlying constructs of measurement items, and to calculate the weights of each construct and its related measurement items. Five constructs of measurement items of corruption, namely (1) immorality, (2) unfairness, (3) opacity, (4) procedural violation, and (5) contractual violation were identified in this paper. This model further uses fuzzy set theory to tackle the problems relating to ambiguity, subjectivity, and imprecision involved in the measurement of corruption, and to quantify the linguistic data of each measurement item. This model was applied in a real public construction project to illustrate its application process.

This model is believed to be particularly useful to a third-party unit responsible for the supervision of a public construction project. Because it can provide an estimated measurement of potential corruption in a public construction project, and disclose in which perspective(s), i.e., immorality, unfairness, opacity, procedural violation, and contractual violation, the potential corruption in which the project mainly lies. Despite this paper focuses on the public construction projects in China, the methodology of this paper can be applied in other countries, especially the developing ones. Thus, the implication of this paper can be expanded internationally and contribute to the global body of knowledge for anticorruption.

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