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International Journal of Project Management 35 (2017) 1597 – 1607

International Journal of Project Management

www.elsevier.com/locate/ijproman

The impact of technical standards on international project performance: Chinese contractors' experience

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Received 23 May 2017; received in revised form 9 September 2017; accepted 12 September 2017
Available online xxxx

Abstract

In international construction, Chinese contractors encounter an ongoing challenge to achieve expected project cost and time performances. This is often attributed to the use of various foreign standards, which are substantially different from Chinese standards. There are limited studies that investigate the reasons why the difference in standards are creating this challenge. This study explores the reason for the difficulties by using a mixed method research with survey data collected from construction companies involving 170 experienced managers who were involved in 115 international projects. It also involved interviews with an additional 76 managers. The findings confirm that Chinese contractors perceived significant difficulties implementing international projects due to the lack of knowledge of the foreign standards. It is concluded that an enhanced understanding of foreign standards, particularly in Middle Eastern countries, will improve cost and time performances in international projects. Strategies of active learning, inter-organizational cooperation and adjustment of talent training mode are suggested for the international contractors to cope with the issue of standards implementation.

Keywords: Comparative analysis; Technical standards; Project performance; Perception; Chinese contractors

1. Introduction

1.1. Overview

Over the last decade, global contractors have greatly increased their involvement and contracting revenue (i.e. from $189.4 billion in 2005 to $521.5 billion in 2014) in international construction markets (Reina and Tulacz, 2015). Chinese contractors therein are playing an increasingly important role and accounted for 17.2% of the international market revenue in 2014, acquiring a greater share than any other country's international contractors (Reina and Tulacz, 2015). According to National Bureau of Statistics of China (2016), Chinese contractors achieved $210 billion overseas contract value in 2015, with an average annual growth rate of 12.3% in the last decade. They have worldwide business across Asia (44.8%), Africa (35.6%), Latin America (10.6%), Europe (5.7%), North America (1.8%) and Oceanic and Pacific Islands (1.4%) according to their reported 2015 turnover (National Bureau of Statistics of China, 2016).

Unlike domestic projects, international projects generally involve participants with different backgrounds and are delivered in relatively unfamiliar locations (Javernick-Will and Scott, 2010). International contractors have to deal with challenges of institutional differences with regards to different regulative, normative and cultural-cognitive institutions in host countries compared with those in domestic markets (Javernick-Will and Scott, 2010; Orr and Scott, 2008). These differences generally

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http://dx.doi.org/10.1016/j.ijproman.2017.09.002
0263-7863/00

cause additional transaction costs and misunderstandings between project participants, which may further lead to time delay and cost overrun (Mahalingam and Levitt, 2007). Many studies have investigated the issue of institutional differences in international project delivery. For example, Chua et al. (2003) identified five risk factors, i.e. business environment discontinuity, regulation obstacles, contractual issues, differences in standards and cultural differences, that can lead to cost overrun in the East Asian construction industry. Han et al. (2007) emphasized the importance of considering market differences and collecting information of host countries from the bidding stage to achieve good profit in international construction projects. Targeting legal differences, Ling and Low (2007) specifically investigated the legal risks that foreign firms encounter in China. Low and Shi (2001) identified cultural differences between Singapore and China associated with the impact of cross-cultural differences on Singaporean construction firms' project effectiveness in China.

As for Chinese international contractors, institutional differences remain a challenge, particularly differences in technical standards (Lu et al., 2009). In different regions or countries, the technical standards, e.g., design and construction standards, can vary significantly (Lee et al., 2016; Kwon and Kareem, 2013). Although scholars have noticed the issue of difference in standards in international project delivery (Javernick-Will and Scott, 2010; Lu et al., 2009; Chua et al., 2003), there is a lack of solid and specific investigation about international contractors' perceptions of standards difference. It is unclear whether the standards difference can affect the overall project performance of international contractors. Based on an empirical survey from Chinese contractors, this study aims to explore the difficulty level of standards implementation perceived by the contractors and the effect of use of standards on overall project performance. Project performances by using Chinese and foreign standards were analyzed by adopting a comparative test. Project performances by using foreign standards were further compared between different regions and different industry sectors. Current views are considered in the following literature review. This is followed in the paper by the research questions and hypotheses, research methodology and results.

1.2. Literature review

Technical standards, establishing the engineering and technical requirements for processes, procedures and methods, are important parts of knowledge about local institutions that contractors should be familiar with in international business (Yates and Aniftos, 1997; Javernick-Will and Scott, 2010). Technical standards from different regions can be substantially different, as the development of technical standards is mostly promoted in a specific country or based on a regional perspective and corresponds to local environmental, technical, legal, cultural and beneficial features (Lane, 1997; Yates and Aniftos, 1997; Geels, 2004; Blayse and Manley, 2004). For example, Lee et al. (2016) pointed out that the US standards about wind loads for the design of pipe-rack structures respectively display about 15% and 25% smaller than the Korean and Euro standards. As with Chinese contractors going globally, more and more Chinese experts and scholars have noticed the difference between Chinese standards and foreign standards, including design standards, construction standards, standards for building materials and components and standards for mechanical and electrical equipment (Gu et al., 2014; Qu, 2013; Tao, 2016; Yan, 2012; Xue, 2006). Table 1 details some examples of the more commonly required technical standards in the construction industry.

Chinese standards were established based on former Soviet Union construction system and can be rather different with the other widely used standards in the world, e.g., American standards, British standards and French standards (Lu et al., 2009). The establishment of Chinese standards system was dominated by government with the characteristics of a planned economy. For example, each sector (e.g., houses, roads, railway, hydraulic engineering, etc.) of the civil engineering industry in China has their own standards for concrete structure design and construction. In contrast, the widely used foreign standards systems such as American and European standards are developed and promoted mainly by industrial force with the principle of voluntariness. This helps western standards such as European concrete standards and American Concrete Institute standards as they consider a wide range of applications and show stronger versatility (Yan, 2012). The requirements of procedures, methods and value of specific parameters between Chinese standards and foreign standards can also be significantly different. For example, American and Chinese standards for design of hydraulic concrete structures (see examples in Table 1) are different in partial coefficients for structural design, design load combinations, minimum requirements of concrete strength, and minimum ratio of reinforcement. The road design standards from America and China (see examples in Table 1) are different in road classification, design vehicle dimensions, consideration of human factor, consideration of traffic volumes and traffic characteristics and sight distances. American concrete testing uses cylindrical or beam specimens, while Chinese concrete testing uses cubic or cuboid specimens. American and Chinese standards for concrete construction (see examples in Table 1) are also different in preparation for concrete placement, batching methods, transportation limits, compaction, curing and protection of works. Chinese and foreign standards for materials and equipment (see examples in Table 1), which are related to purchasing activities in international projects, can also be different in the likes of: product classification, quality requirements and testing methods.

The impact of technical standards on companies' international business can be complex. Mangelsdorf (2011) found that pure Chinese standards have negative influences while Chinese international standards have positive influences on European exports. This finding indicates that the effect of standards on international trade is related to the uniformity of domestic and foreign standards. The difference in technical standards can play a role of technical barriers for firms' international business. Chen et al. (2006) also found that technical standards in developed countries reduce companies' export in developing countries. The difference in standards can raise the cost of companies' export activities and reduce the likelihood of exporters' market entry (Chen et al., 2006). However, Marette

Table 1
Some examples of commonly required technical standards in the construction industry.

Standards reference	Name	Source
Design standards		
Design for hydraulic concrete structures		
EM 1110-2-2014-03	Strength design for reinforced-concrete hydraulic structures	USACE, U.S.A.
ACI 318M-11	Building code requirements for structural concrete and commentary	ACI, U.S.A.
DL/T 5057-2009	Design specification for hydraulic concrete structures	NEA, China
Design for roads		
AASHTO GDHS-6:2011	A policy on geometric design of highways and streets	AASHTO, U.S.A.
JTG D20-2006	Design specification for highway alignment	MT, China
CJJ 193-2012	Code for design of urban road alignment	MHURD, China
CJJ 37-2012	Code for design of urban road engineering	MHURD, China
Construction standards		
Concrete making and curing		
ASTM C31/C31M-15	Standard practice for making and curing concrete test specimens in the field	ASTM, U.S.A.
SL 352-2006	Test code for hydraulic concrete	MWR, China
DL/T 5150-2001	Test code for hydraulic concrete	SETC, China
Concrete construction		
ACI 207.5R-11	Report on roller-compacted mass concrete	ACI, U.S.A.
ACI 304R-00	Guide for measuring, mixing, transporting, and placing concrete	ACI, U.S.A.
ACI 309.5R-00	Compaction of roller-compacted concrete	ACI, U.S.A.
DL/T 5112-2009	Construction specification for hydraulic roller compacted concrete	NEA, China
DL/T 5144-2015	Construction specification for hydraulic concrete	NEA, China
SL 677-2014	Construction specification for hydraulic concrete	MWR, China
Underground construction		
EM 1110-2-2901	Tunnels and shafts in rock	USACE, U.S.A.
DL/T 5099-2011	Technical specification for excavation of underground works on hydraulic structure	NEA, China
JTG F60-2009	Technical specification for construction of highway tunnel	MT, China
Standards for building materials and components		
Cement		
ASTM C150/C150M-16	Standard specification for Portland cement	ASTM, U.S.A.
ASTM C1157/C1157M-11	Standard performance specification for hydraulic cement	ASTM, U.S.A.
ASTM C1329/C1329M-15	Standard specification for Mortar cement	ASTM, U.S.A.
GB 175-2007	Common Portland cement	AQSIQ, China
Building hardware		
BS EN 13126-1:2011	Building hardware. Hardware for windows and door height windows. Requirements and test methods. Requirements common to all types of hardware	U.K.
JG/T 212-2007	Building hardware for windows and doors - General requirements	MHURD, China
Standards for mechanical and electrical equipment		
Hydraulic turbines, storage pumps and pump-turbines		
NF C55-401	Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pumps-turbines	France
IEC 60193	Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests	IEC
GB/T 15613.1-2008 GB/T 15613.2-2008 GB/T 15613.3-2008	Model acceptance tests of hydraulic turbines, storage pumps and pump-turbines. Part 1: General rules. Part 2: Main hydraulic performance test. Part 3: Additional performance test	AQSIQ, China
Road monitoring device		
ASTM E2300-09	Standard specification for highway traffic monitoring devices	ASTM, U.S.A.
GB/T 18567-2010	Surveillance and control system configuration for freeway tunnel	AQSIQ, China
JT/T 965.1-2015 JT/T 965.2-2015	Test method for expressway surveillance and control system software. Part 1: Function testing. Part 2: performance testing	MT, China

Note: AASHTO: American Association of State Highway and Transportation Officials; ACI: American Concrete Institute; ASTM: American Society for Testing and Materials; AQSIQ: General Administration of Quality Supervision, Inspection and Quarantine; IEC: International Electrotechnical Commission; MHURD: Ministry of Housing and Urban-Rural Development; MT: Ministry of Transport; MWR: Ministry of Water Resources; NEA: National Energy Administration; SETC: State Economic and Trade Commission; USACE: United States Army Corps of Engineers.

and Beghin (2010) pointed out that the restriction of technical standards on foreign firms' international business also depend on the companies' own efficiency or capability. When foreign companies are more capable and efficient, the protectionism of standards will not exist and the difference in standards will not raise additional cost for them (Marette and Beghin, 2010).

Maskus et al. (2000) claimed that there was a lack of studies on how companies in developing counties respond to the difference between domestic and foreign standards when entering international markets. This research gap still exists in the international construction industry. As Chinese contractors are playing a significant role in international construction markets, their perceptions of the difference in standards and the extent to which their overseas project implementation can be affected by the standards difference are still unclear.

1.3. Research questions and hypotheses

To understand the influence of standards implementation on project performance of Chinese international contractors, this study needs to answer the following questions:

- What are Chinese contractors' perceptions of the difference in standards when delivering international projects? Do they perceive significant difference in implementing foreign standards and Chinese standards in overseas projects?
- What are Chinese contractors' overall project performances? Does the adoption of standards affect Chinese international contractors' overall project performances?
- When using foreign standards, is there difference about Chinese international contractors' overall project performances in different regions?
- When using foreign standards, is there difference about Chinese international contractors' overall project performances for different industry sectors?

Foreign standards can be substantially different from Chinese standards not only in specific requirements but also in the underlying philosophical approach. Thus, it can be very difficult for Chinese contractors to adapt to the implementation of foreign standards. Once the difference in standards has been identified, contractors require additional resources to address the differences yet they still often encounter issues such as: errors requiring rework, delays as staff learn new practices and adapt to unfamiliar standards. These additional inputs and encountered issues can impede the achievement of overall project performances. Although Chinese contractors have strong commercial backing and enjoy an advantage of relatively cost effective workforce and materials, they are criticized for their poor efficiency of project management (Lu et al., 2009). Chinese contractors may not be competent enough to overcome the challenge of difference in standards by adjusting their management in a timely way. Thus, two hypotheses are proposed.

H1. *When delivering international projects, Chinese contractors perceive greater challenges in the implementation of the foreign standards in comparison to the use of Chinese standards, in the areas of (a) design standards; (b) construction standards; (c) standards for building materials and components and (d) standards for mechanical and electrical equipment.*

H2. *The overall project performances (a) cost, (b) quality and (c) time of Chinese international contractors using Chinese standards are better than those using the foreign standards.*

Apart from technical standards, other factors such as natural environment, social culture, political and economic conditions can also affect project delivery. In different regions, project performances of Chinese contractors can be different. In addition, as different industry sectors have different technical and managerial requirements, contractors' project performances for different sectors can be different. Thus, another two hypotheses were proposed.

H3. *When using foreign standards, the overall project performances (a) cost, (b) quality and (c) time of Chinese international contractors are regionally dependent, considering (i) Southeast Asia* vs. *Sub-Sahara Africa; (ii) Southeast Asia* vs. *Greater Middle East and (iii) Sub-Sahara Africa* vs. *Greater Middle East.*

H4. *When using foreign standards, the overall project performances (a) cost, (b) quality and (c) time of Chinese international contractors are dependent on the types of projects, considering power projects* vs. *transport and general building projects in the regions of (i) Southeast Asia; (ii) Sub-Sahara Africa and (iii) Greater Middle East.*

2. Research methodology

The aim of this study is to investigate international contractors' perceptions of standards difference and to analyze its effect on overall project performance. To test the hypotheses, a mixed method combining quantitative and qualitative approaches was used (Creswell, 2013). The quantitative analysis using comparative tests presents the overall outcomes of Chinese contractors' standards implementation in overseas market. The qualitative analysis, done using interviews helps understand their overseas standards practice more specifically. The mixed methods approach helps draw a holistic picture of Chinese contractors' implementation of technical standards in international projects.

2.1. Data collection

A combination of e-questionnaire survey and interviews was undertaken for Chinese contractors. The research complied with research ethics guidelines stipulated by Tsinghua University.

The e-questionnaire was designed to investigate Chinese managers' perceptions of standards implementation in their engaged international projects. Each respondent was asked to answer the questions according to their experience in a specific project. Questions about the project and respondent's background information included project name, contract size, industry sector, located country, respondent's occupation in the project and overall working years abroad. Respondents were asked to provide the details of the project including specific standards involved and the difficulty encountered. Specific questions included the consideration of design standards, construction standards, standards for building materials and components and standards for mechanical and electrical equipment. Respondents were also asked to comment the overall project performances (i.e. cost, quality and time). A 5-point Likert scale was used.

E-questionnaires were sent to 17 Chinese construction companies. These contractors all had rich experience in overseas construction business, as they all had over 10 years' overseas experience and were with over $30 million contract value. The questionnaire was distributed to managers with experience in international projects.

Table 2
Countries included in this study.

Regions	Countries	Sample distribution
Sub-Sahara Africa	Angola, Cameroon, Congo-Brazzaville, Congo-Kinshasa, Cote d'Ivoire, Equatorial Guinea, Ethiopia, Kenya, Gabon, Guinea, Madagascar, Mauritius, Namibia, Tanzania, Uganda, Zambia, Zimbabwe	34.1%
Greater Middle East	Algeria, Libya, Mali, Morocco, Niger, Pakistan, Qatar, Saudi Arabia, Senegal, Sudan, Tunisia, United Arab Emirates	26.5%
Southeast Asia	Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Thailand, Vietnam	21.2%
Latin America	Bolivia, Ecuador, Honduras	5.9%
Middle Asia	Kazakhstan, Tajikistan, Uzbekistan	4.7%
East Europe	Armenia, Georgia	2.9%
South Asia	Nepal, Sri Lanka	2.4%
Oceania	Fiji	1.8%
East Asia	Mongolia	0.6%

429 questionnaire responses were received. These were checked for the validity by observing their completion time and the responses with an unrealistically short completion time (<2 min) were removed to ensure the responses selected were answered with sufficient thought. The sample was further checked and responses with constant answers or special shapes were deleted (Jiang et al., 2016). Responses based on projects that had not started construction were also deleted. In total, 65 responses were deleted. Further, to ensure the accuracy of sample, 194 responses from managers with only 1–5 years' overseas experience were excluded. The remaining respondents with different disciplines showed no significant difference in their perceptions of standards implementation. For example, the comparison of the difference between project managers and design managers in term of foreign standards implementation showed $t = -0.88$ ($p = 0.395$). Thus, they were analyzed as a single grouping. Finally, 170 valid responses were retained in the sample.

The 170 responses involved 115 overseas projects of Chinese contractors. The sample distribution by project contract size ($ million) is ≤20 (5.9%), 20–50 (14.7%), 50–100 (17.6%), 100–500 (45.3%) and >500 (16.5%). 50.6% of the respondents were engaged in the power industry sector, 37.0% were from transport and general building projects and other kinds of sectors (including water supply, mining and sewerage/solid waste) accounted for 12.4%. The involved projects are located in 49 countries shown in Table 2. The sample can adequately represent the population, as majority of Chinese contractors are working on overseas projects in the sectors of power and transport infrastructure construction and their overseas business is mainly located in Asia and Africa.

To investigate Chinese contractors' practice of standards implementation in international projects, face-to-face interviews with another 76 managers from seven Chinese contractors were conducted. All interviewees had rich experience in overseas projects and they were asked to share their perceptions of difference in standards and the issues in standards implementation in overseas projects.

2.2. Data analysis

The comparative studies were performed by using independent-samples *t*-test (Navidi, 2011). By running Levene's test for equality of variances, it was decided to use equal variances assumed *t*-test or equal variances not assumed *t*-test (Gürcanlı et al., 2015). The commercial software SPSS 24 was used to perform the quantitative analyses.

The results were further analyzed and discussed by referring to the interviews. The mixed analysis helps provide an in-depth understanding of Chinese contractors' standards practice in international projects. The results are shown in Section 3.

3. Results

3.1. Survey results

The distribution of standards used in international projects of Chinese contractors from the survey data was presented in Table 3. Comparison of Chinese contractors' experience on implementation of foreign standards and Chinese standards (i.e. difficulty level of standards implementation and overall

Table 3
Distribution of standards used in international projects of Chinese contractors.

Standards	N	AS	EN	BS	NF	DIN	AS/NZS	CS	Others
Sub-Sahara Africa	58	13.9%	14.9%	17.8%	17.8%	5.0%	–	23.8%	6.9%
Greater Middle East	45	27.1%	16.5%	16.5%	20.0%	4.7%	–	7.1%	8.2%
Southeast Asia	36	15.6%	2.2%	24.4%	–	–	2.2%	48.9%	6.7%
Latin America	10	55.6%	16.7%	5.6%	–	–	–	22.2%	0.0%
Middle Asia	8	25.0%	–	16.7%	8.3%	8.3%	–	–	41.7%
East Europe	5	50.0%	33.3%	16.7%	–	–	–	–	0.0%
South Asia	4	28.6%	14.3%	28.6%	–	–	–	14.3%	14.3%
Oceania	3	25.0%	–	25.0%	–	–	50.0%	–	–

Notes: AS – American standards; EN – European Union standards; BS – British standards; NF – French standards; DIN – German standards; AS/NZS – Australian/New Zealand standards; CS – Chinese standards. Countries included in this study are shown in Table 2.

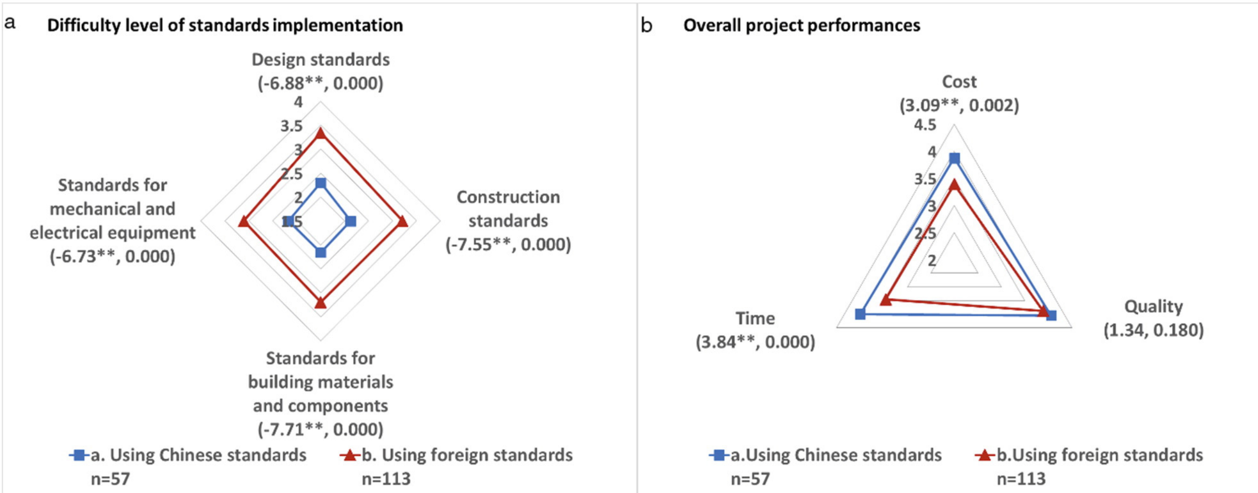

Fig. 1. Comparison of Chinese contractors' experience between using Chinese standards and using foreign standards: (a) Difficulty level of standards implementation; and (b) Overall project performances. t and p values are shown in the parentheses; **. Significance level < 0.01.

project performance) was conducted with the results in Fig. 1. The results confirm that when adopting foreign standards, Chinese contractors encountered more difficulty and obtained significant lower project cost and time performances. Focusing on implementation of foreign standards, project performances in different regions (i.e. Southeast Asia, Sub-Sahara Africa and Greater Middle East) were further compared with the results presented in Fig. 2. The results indicate that Chinese contractors' project time and cost performances are also region-dependent. To further explore the disparity of project performances between different industry sectors when using foreign standards, the comparison was undertaken between power projects and transport and general building projects in the three regions with the results presented in Fig. 3. The results show that in Greater Middle East, Chinese contractors had significantly poorer cost and time performances in transport and general building projects than in power projects.

The significant findings from the statistical analyses are as follows.

- The results in Fig. 1a support H1a-1d. Chinese international contractors perceive significantly greater challenges of the implementation of foreign standards than the use of Chinese standards, in all the areas of design standards (significant at $p < 0.01$), construction standards (significant at $p < 0.01$), standards for building materials and components (significant at $p < 0.01$) and standards for mechanical and electrical equipment (significant at $p < 0.01$).

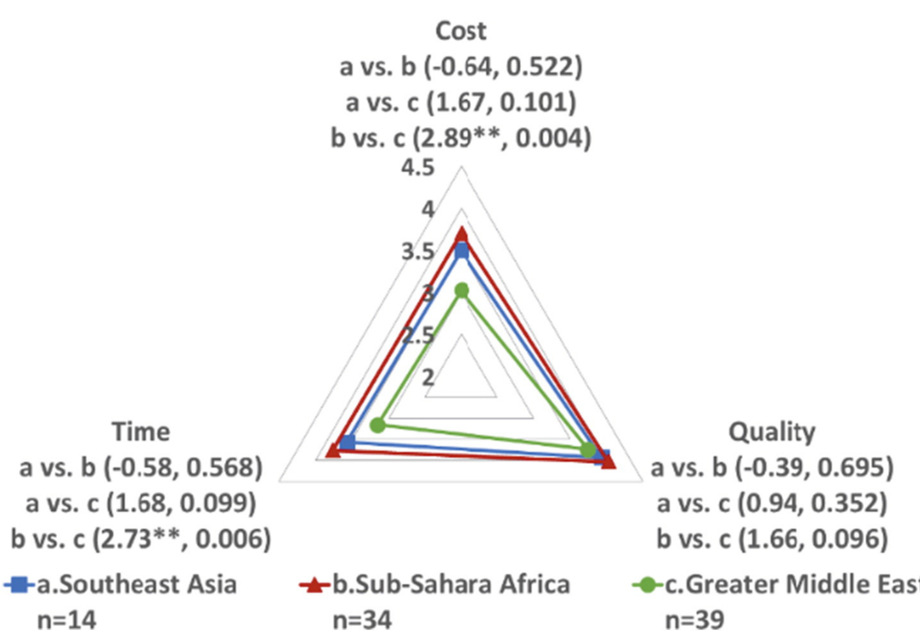

Fig. 2. Comparison of overall project performances in different regions when using foreign standards. t and p values are shown in the parentheses; **. Significance level < 0.01.

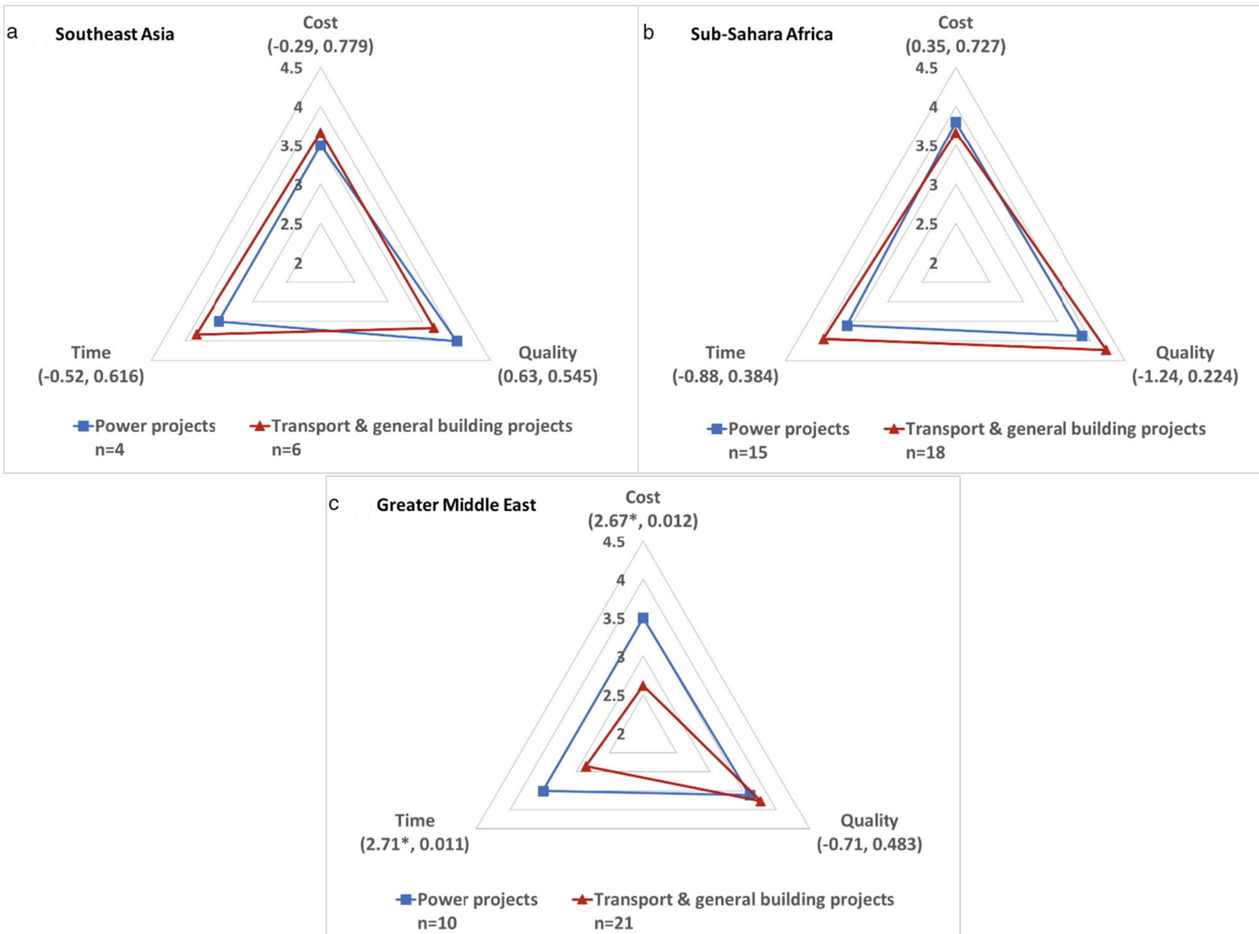

Fig. 3. Comparison of overall project performance between power projects and transport & general building projects when using foreign standards: (a) In Southeast Asia; (b) In Sub-Sahara Africa; and (c) In Greater Middle East. t and p values are shown in the parentheses; *. Significance level < 0.05.

- The results in Fig. 1b support H2a and H2c. Chinese international contractors achieved significantly better cost performance (significant at $p < 0.01$) and time performance (significant at $p < 0.01$) by using Chinese standards than those by using the foreign standards.
- The results in Fig. 2 support H3a-iii and H3c-iii. When using foreign standards, Chinese international contractors achieved significantly better cost performance (significant at $p < 0.01$) and time performance (significant at $p < 0.01$) in the region of Sub-Sahara Africa than those in Greater Middle East.
- The results in Fig. 3c support H4a-iii and H4c-iii. When using foreign standards in the region of Greater Middle East, Chinese international contractors achieved significantly better cost performance (significant at $p < 0.05$) and time performance (significant at $p < 0.05$) in power projects than those in transport and general building projects.

The other hypotheses are not supported as the statistical analyses did not show any significant relationships.

3.2. Face-to-face interviews

In accordance with the survey results in Table 1, the interviews also demonstrate that Chinese standards are mainly accepted in some regions or countries from Southeast Asia and Sub-Sahara Africa. Factors influencing the adoption of standards in international projects can be complex. Three managers (project managers and design chief) involved in projects in Cambodia, Vietnam, Laos, Argentina and Honduras summarized that selection of standards in different regions is related to "*their colonial history and current political bias*". In Latin America, American standards are mainly preferred. In Africa, British and French standards are widely preferred. In Southeast Asia, which is "*at the initial stage of standards system building*", has a "*mixed using of European, American and Chinese standards*". Factors such as "*independence of the politics and economy of the region or country*", "*perception of China, such as Chinese politics, economy and culture*", "*degree of perfection of the local engineering standards system*" and "*government's control on projects*" all have influences on clients' preference of Chinese or foreign standards.

Investment mode and funding source can also affect the adoption of standards. For example, Chinese contractors achieved the hydropower projects of Nam Ou River in Laos by adopting the delivery method of "*Engineering, Procurement and Construction plus Financing*" and all used Chinese standards in these projects. An oil project in Venezuela, at first was schemed by Japanese and South Korean companies using European standards, but later allowed to use Chinese standards for planning and design after obtaining Chinese funds. However, there were also many cases of projects with Chinese funds, which designated the use of Chinese standards in contracts, but in practice, were implemented using foreign standards. A marketing director said, "*In Europe, a Chinese-funded project wrote in the contract to use Chinese standards, but actually it didn't implement Chinese standards*." A deputy director of international business department said, "*For our project in Argentina, it was funded from China but still not accepted Chinese standards*." One reason demonstrated by a director of international office is that foreign clients and consulting engineers, educated under the European and American construction system, are unfamiliar with Chinese standards that were "*developed based on former Soviet Union standards system*" and tend to require using foreign standards.

Many interviewees had perceived significant differences between some international standards and Chinese standards. As for design and construction standards, they perceived that the logic modes of western standards and Chinese standards are different. European and American standards are "*principle-based*", which require "*detailed calculations step by step*" and do not accept the results without calculated evidence. However, Chinese standards are "*template-based*", which directly provide parameters or schemes based on "*practical experience*". Thus, Chinese standards can be more "*specific*" and show how to work in detail, while western standards are relatively "*vague*" and generally provide some calculation principles without specific provisions. As an interviewed deputy chief engineer described, the implementation of Chinese standards is like "*knowing how to do it but no knowing why to do it*". In addition, western standards emphasize more aesthetics and human factors than Chinese standards. Under western standards, engineers are given more leeway for design and construction. Consequently, the engineers will be charged if accidents or errors happen. However, in China, "*if engineers do the design and construction in compliance with the standards, the responsibility when things go wrong does not belong to the engineers but belongs to the standards*".

The interviews also provided many examples of the specific differences in requirements of foreign standards and Chinese standards. For example, "*foreign standards for the seismic evaluation can be based on the method of deformation analysis, while Chinese ones use the method of fuzzy comprehensive evaluation*". "*Concrete sieve size in China is in centimeters while foreign sieve is in inches*". "*The foreign dam water proofing technique doesn't distinguish different dams, while it does in China*". As for the difference in construction standards, a general secretary provided an example of the difference in reinforced concrete construction between German and Chinese standards. DIN standards avoids the use of steel welding, which is not conducive for quality inspection and monitoring. DIN standards also refuse over 30% lap steel bars in sections, and require thickness of protective layers to be 5–7 cm that can be twice of Chinese one. Standards for building materials and equipment can also be different. For example, western standards for products require supply of detailed specifications such as types and manufacturers of components and guides for periodic maintenance, while products from China generally fail to provide enough specifications. As an interviewed director for purchasing and installation of mechanical and electrical equipment said, water pumps purchased from China did not "*provide enough specifications, e.g., sizes/types and sealing property of the components and the vulnerable parts*". An electromechanical manager also pointed out that they were unable to provide the set of process documents that monitor the whole production process required by American Society of Mechanical Engineers (ASME) standards for tubular products.

When facing the difference in standards, Chinese contractors tended to arrange the schemes by using Chinese standards first. In many cases, the schemes were not approved by foreign consulting engineers or supervisors, and renegotiation and rework were unavoidable. A deputy manager involved in a hydropower project in Gabon said, "*We submitted the schemes by using Chinese standards, and the consulting company conducted the examination by using European standards. If the schemes were not approved, we would negotiate with them and change the schemes following their requirements*." It is suggested that learning and using foreign standards directly for the design can instead help save time and cost, as a director of international office said, "*It is a waste of time to design by using Chinese standards and try to make explanations to the consulting engineers. Sometimes it is better to design directly using American standards. It can save a lot of time for the approvals*."

Working as general contractors for Engineering, Procurement and Construction (EPC) projects, Chinese contractors significantly noticed the issue of difference in standards, especially for design that can affect the overall project implementation. Dealing with the difference in standards at the design stage had been "*a headache problem*" for them. In an EPC hydropower project in Ecuador, the contractor could not reach an agreement on parameter and formula for design with the consulting engineer, which further resulted in a "*four month delay of approval of drawings*" equivalent to "*the loss of about 3 million dollars*". The interview explained that Chinese design company failed to adapt to foreign standards during "*the transformation from institutions to business firms*". The cooperation between construction and design companies were not sufficient due to their conflicts of interest, which further resulted in that the designer lacked motivation for design optimization and "*made mistakes in weighing the pros and cons*". Lack of trust and insufficient communication between general contractors and their designers can hinder their timely dealing with the standards challenge. A deputy chief engineer from a design company pointed out that "*some contractors didn't allow the designer to see the business parts of the general contract*" and some general contractors "*might think it unnecessary to involve our participation in some meetings and didn't notify us*". Consequently, designers could miss some information, resulting in inaccuracy or errors of design schemes.

The unfamiliarity with each other's standards could lead to lengthy communication between the contractors and consulting engineers. As a quality manager in a mega hydropower project in Ecuador said, it was "*a tough job*" to explain to foreign consulting engineers "*why to set certain values of some parameters*" in the design schemes that used Chinese standards. The engineers did not allow "*empiric values*" and required some cases or experiments to demonstrate them. The large time difference could also make "*the communication between the onsite design representative and domestic headquarter very inefficient*". In the project, the contractor finally had to hire another Chinese design company and a French design company to do the calculation at the same time to persuade the consulting engineer. In addition, the big mobility of design engineers could further aggregate this issue. Design companies sometimes replaced their onsite design representative "*half a year*" owing to their busy business. A deputy chief engineer said, "*When the consulting engineer became familiar with the design method and schemes from a design engineer, the engineer was replaced by a new one. They had to relearn and spend additional time to be familiar with each other.*"

It is indicated that good inter-organizational relationships and active and effective communication among project participants are essential to overcome the unfamiliarity of difference in standards. A deputy manager shared their successful experience in an EPC project and suggested to arrange "*coordination meetings with the client, consulting engineers, construction and design companies to discuss the design idea, standards issues and major schemes in depth*". Adequate communication and winning approval from all the participants before the detailed design could effectively avoid "*rework and time delay*".

The lack of consideration of difference in standards at the bidding stage can lead to poor project performance. Some requirements of foreign standards could be higher than Chinese ones and failing to consider them ahead of schedule could cause cost overrun. A general secretary blamed that "*we sometimes neglected some differences in standards when preparing the bidding*", which could cause "*great losses*". He gave an example that they failed to consider the complexity of foreign grouted bolt construction standards that need backing plate or concrete base with nuts at the bidding stage. An electromechanical director also criticized the issue, "*there were many cases that failing to comprehensively learn the technical standards at the bidding stage led to delay and cost overrun in the project implementation*". He gave an example of a hydropower project in Cameroon, which required using hydraulic gate made by stainless steel. Chinese standards, however, had no such specifications. The contractor's neglect of this requirement at the bidding stage resulted in the cost rising from 10 million dollars to 25 million dollars. In another hydropower project in Madagascar, the use of European materials handling federation (FEM) standards with higher requirements than Chinese standards increased the cost of mechanical and electrical equipment. The interviewed director further pointed out that "*lots of time at the bidding stage was used in translation*" and "*time left for the technicians is very little*", which made losses in projects such as the case of stainless steel gate "*often occur*". Thus, the interviewed secretary suggested to "*arrange the technical staff with construction experience to review the part of construction techniques in contracts when bidding*" and "*summarize the lessons and experience, and share them regularly*" to avoid the "*recurring problems*".

Sometimes the inconsistency between foreign and Chinese standards could also consume additional cost and time. A quality manager provided an example of using Chinese machines to bend American steel bars, which are different in some physical and chemical performance indicators with Chinese ones. American steel bars had higher carbon content than that from China, which made their strength about 30 MPa higher but their toughness worse with the bending radius of "*6–8 times the diameter of the steel bars*", larger than Chinese bending radius of "*5 times the diameter of the steel bars*". Consequently, American steel bars cracked when bended by machines brought from China. The contractor did not realize the reason first and had to spend additional time to do experiment and figure it out.

From the company-level perspective, the contractors should also review their talent training mode to deal with the standards challenge. A deputy executive showed that Chinese contractors' talent training aims to develop "*versatile talents*" competent on both technique and management. The experienced managers will be promoted to "*the top*" and do not have to "*implement a certain project*" any more. Although this training mode is good for employees' comprehensive development, it can also lead to that the managers' technical and managerial skills are not "*utilized to the maximum extent*" and cannot match those of "*foreign professional engineers with decades of experience in some specific practice*". The lack of experienced employees in specific projects can cause the inefficiency in dealing with the challenge of difference in standards.

Apart from being affected by standards adoption, Chinese contractors' international project performance can also be region-dependent and specifically they encountered more challenges in Greater Middle East (see Fig. 2). A manager with experience in Sudan indicated that local high temperature could induce some losses, such as "*the spacer of hydraulic gate breaking down due to the high temperature*" during transportation. Demonstrated by a manager with project experience in Pakistan, "*non-traditional safety problems*" such as terrorist attacks and plunder can also have negative influences on project implementation. The manager said, "*There was a Road Open Day when the road was open for Chinese to pass through. It could cost one month for the project personnel to get to the project site.*" They were threatened by Taliban fighters, and once encountered a hostage incident and had to stop the project. The contractors also had to deal with the issues of religious difference, e.g., the decrease of working time due to prayer times or restricted working hours during Ramadan. Labour issues could also raise project cost and time. For example, employees from Niger have high requirements of salaries and welfare being equal to French ones. A deputy director of technical center said, "*They rest* 21 days *per* 3 months *and have strong sense to protect rights. The local labour union requires the labour rest on Sundays. The wages double for work overtime. If not satisfied, they would strike.*" A manager with rich project experience in Middle East like Saudi Arabia and Kuwait also said, "*The local people generally don't do the basic construction work. We hired labour from India, Pakistan and Philippines. However, according to the contract, it required a* 10–20% *employment rate of local labour. We had to spare some local people to meet the contract requirement.*"

4. Discussion

Implementation of technical standards is critical for the cost, time and quality performance of construction projects. Technical standards are closely connected with core project activities including design, construction and equipment and materials purchasing. Different technical standards can have different requirements of design modes, construction methods, and types and quality of equipment and materials, which further determine project cost, schedule and quality. Behind the explicit requirements lying in specific articles, technical standards can in essence imply the thinking logic of engineers and the habits and preferences of local industrial practice, which can be very challenging for international contractors to handle and manage during project delivery. Due to the historical factor and cultural difference, Chinese standards system is substantially different from western standards system (e.g., British, French and American standards). Although China is endeavoring to promote the spread of Chinese standards in international construction markets by investing Chinese money, the actual adoption of standards can be complex due to political, economic and cultural factors. Even in Southeast Asia where China has a relatively great political and economic influence, the adoption of Chinese standards is also limited. In most circumstances, Chinese contractors have to deal with the challenge of implementing foreign standards when delivering international projects.

When using foreign standards, Chinese contractors significantly encountered poorer cost and time performance. Although the substantial differences in standards can be excused as the basic cause, their struggling in implementing foreign standards should be largely owing to the lack of proactive and effective management responses in dealing with the challenge.

Insufficient preparations of integral knowledge about difference in standards at the bidding stage could lead to unreasonable bidding prices and durations, which could generate great pressure for the contractors to satisfy unexpected higher requirements of foreign standards. The essential learning activities at the bidding stage were deferred to the stage of project execution. Sometimes, the learning of foreign standards could be further deferred to the moment of approval refusal and dispute occurrence, as they would like to do the schemes by using Chinese standards first. They had to spend more time and money to modify the schemes, associated with renegotiation with clients or consulting engineers, lengthy communication among participants and rework in design and construction.

Insufficient inter-organizational cooperation could further aggravate the issue. As the EPC approach has been a usual project delivery method for Chinese contractors in the international construction industry, the main contractors often cooperate with Chinese design companies to deliver overseas EPC projects. The misalignment of interests between them could decrease the designers' initiative of learning and could lead to insufficient information sharing between them, which could further affect the adaptability and acceptability of design schemes. The contractors can seek to extend inter-organizational cooperation networks and hire foreign design and consulting companies that are more familiar with related foreign standards to help them deal with the standards challenge. The emphasis on inter-organizational cooperation also goes for the contractors' relationships with consulting engineers or supervisors. The passive cooperation and communication with consulting engineers generally led to that the contractors failed to adequately understand the requirements of foreign standards beforehand. The inadequate understanding of requirements then could cause rework with a waste of time and money.

It is also indicated that talent training mode has relationship with the contractors' insufficient dealing with the standards challenge. The overemphasis on development of versatile talents leads to the insufficiency of maximizing the utilization of experienced specialists. This training mode suggests experienced managers to be promoted to the top management of headquarters where career development and remuneration are better. This would lead to that new projects in local markets have to involve new inexperienced managers and engineers and a re-learning process is unavoidable.

Apart from difference in standards, international project performances can be affected by other regional factors like tough natural environment (e.g., high temperature), unstable political situation (e.g., terrorism), significant cultural difference (e.g., religion difference) or difficult labour management. This may be the reason why the contractors perceived poorer cost and time performances in Greater Middle East (see Fig. 2). In addition, the cost and time performances in transport and general building projects were poorer than those in power projects when using foreign standards in Greater Middle East (see Fig. 3). The reason may be that these Chinese contractors are more experienced in power construction as they have been working on it for decades while the delivery of transport and general building projects is relatively new to them. The implementation challenges in Greater Middle East mentioned above could also aggregate difficulties for their delivery of transport and general building projects. The findings indicate that in dealing with the challenge of implementing foreign standards, international contractors should pay more attention to the projects in areas with larger regional differences and with less industrial experience.

5. Conclusions

As existing studies lack research on the influence of difference in technical standards on international project implementation, this paper conducts a comprehensive investigation of the issue of technical standards in international projects based on data collected from Chinese contractors. The research questions and hypotheses in Section 1.3 are investigated and tested with the findings as follows.

- The study confirms that Chinese contractors perceived significant difference between foreign standards and Chinese standards. They perceived greater challenges in implementing foreign standards in international projects.
- The implementation of standards can affect the overall project performances. When using foreign standards, the contractors had poorer project performances, especially of cost and time.
- When using foreign standards, Chinese contractors perceived poorer cost and time performances in Greater Middle East than in Sub-Sahara Africa. The finding indicates that other regional factors (e.g., natural environment, political

situation, religious differences and characteristics of local labour) can also affect international project performance.

- When using foreign standards, in Greater Middle East, Chinese contractors also perceived poorer cost and time performances in transport and general building projects than those in power projects. The finding indicates that industrial factor can also influence the overall performance of international projects.

To deal with the challenge of standards difference, the international contractors are suggested to 1) pay more attention to their learning activities not only during project implementation but also at the bidding stage, 2) build inter-organizational cooperative relationships based on mutual goals and facilitate effective communication among project participants, and 3) improve talent training mode to develop and utilize employees' professions.

The findings were based on the data from Chinese contractors. Future studies should investigate whether the issue of standards difference can affect the overall project performance of other contractors, e.g., foreign contractors in China. A comparative analysis between the practices of different contractors can help generate significant implications for international project management. A future study is also necessary to investigate the parallel side that explores the impact of technical standards on project performance from the client perspective.

Conflict of interest

There is no conflict of interest.

Acknowledgements

We would like to thank the National Natural Science Foundation of China (Grant Nos. 51379104, 51579135, 51079070), the State Key Laboratory of Hydroscience and Engineering (Grant Nos. 2015-KY-5 and 2013-KY-5) and Major Science and Technology Research Project of Power China (Grant Nos. DJ-ZDZX-2015-01-02, DJ-ZDZX-2015-01-07). Thanks are also expressed to the University of Melbourne (Grant No. 121914) for hosting a visiting scholar. Special thanks are also given to the respondents for their generous contributions during the survey.

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